विज्ञान एवं प्रौद्योगिकी विभाग
DEPARTMENT OF
SCIENCE & TECHNOLOGY

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

INDIAN TEXTILES & APPAREL SECTORIAL SYSTEM OF INNOVATION (ITASSI)

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

March 2023

www.unido.org

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Disclaimer

INDIAN TEXTILES & APPAREL SECTORIAL SYSTEM OF INNOVATION (ITASSI) - MEASUREMENT, ANALYSIS AND POLICY RECOMMENDATIONS

UNIDO-DST Survey Report

March 2023 Vienna, Austria

विज्ञान एवं प्रौद्योगिकी विभाग
DEPARTMENT OF
SCIENCE & TECHNOLOGY

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

डॉ. जितेन्द्र सिंह
राज्य मंत्री (स्वतंत्र प्रभार)
विज्ञान एवं प्रौद्योगिकी मंत्रालय;
राज्य मंत्री (स्वतंत्र प्रभार) पृथ्वी विज्ञान मंत्रालय;
राज्य मंत्री, प्रधान मंत्री कार्यालय;
राज्य मंत्री कार्मिक, लोक शिकायत एवं पेंशन मंत्रालय;
राज्य मंत्री परमाणु ऊर्जा विभाग तथा
राज्य मंत्री अंतरिक्ष विभाग
भारत सरकार

सत्यमेव जयते

Dr. JITENDRA SINGH
Minister of State (Independent Charge)
of the Ministry of Science and Technology;
Minister of State (Independent Charge)
of the Ministry of Earth Sciences;
Minister of State in the Prime Minister's Office;
Minister of State in the Ministry of Personnel,
Public Grievances and Pensions;
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.

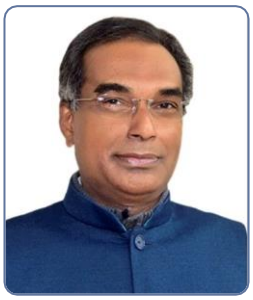
(**Dr. Jitendra Singh**)
MBBS (Stanley, Chennai)
MD Medicine, Fellowship (AIIMS, NDL)
MNAMS Diabetes & Endocrinology

Anusandhan Bhawan, 2, Rafi Marg
New Delhi - 110001
Tel. : 011-23316766, 23714230,
Fax. : 011-23316745

South Block, New Delhi – 110011
Tel. : 011-23010191 Fax : 022-23017931
North Block, New Delhi – 110001
Tel. : 011-23092475 Fax : 011-23092716

सचिव
भारत सरकार
विज्ञान एवं प्रौद्योगिकी मंत्रालय
विज्ञान एवं प्रौद्योगिकी विभाग
Secretary
Government of India
Ministry of Science and Technology
Department of Science and Technology

डॉ. एस. चंद्रशेखर
Dr. S. Chandrasekhar



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)

Technology Bhavan, New Mehrauli Road, New Delhi - 110016
Tel: 0091 11 26511439 / 26510068 | Fax: 00 91 11 26863847 | e-mail: dstsec@nic.in | website: www.dst.gov.in

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
Deputy to the Director General and Managing Director,
Directorate of Technical Cooperation and Sustainable Industrial Development,
United Nations Industrial Development Organization (UNIDO)

डॉ. अखिलेश गुप्ता
Dr. Akhilesh Gupta

वरिष्ठ सलाहकार एवं प्रमुख
नीति समन्वय एवं कार्यक्रम प्रबंधन प्रभाग
विज्ञान और प्रौद्योगिकी विभाग
विज्ञान और प्रौद्योगिकी मंत्रालय
भारत सरकार
Senior Adviser & Head
Policy Coordination & Programme Management Division
Department of Science and Technology
Ministry of Science and Technology
Government of India

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)

Technology Bhawan, New Mehrauli Road, New Delhi - 110016
Phone: +91-11-26862512 Email: akhilesh.g@nic.in, gakhilesh2008@gmail.com, Website: www.dst.gov.in

Contents

List of Tables

List of Figures

List of Box

Acronyms

4IR	Fourth Industrial Revolution
ADP	Advanced Digital Production
AI	Artificial Intelligence
AIC	Atal Incubation Centre
AIF	Alternative Investment Fund
AISA	Apparel Industry Sustainability Action
AM	Additive Manufacturing
AMCoE	Centre of Excellence in Additive Manufacturing
AMFII	Association of Man-Made Fibre Industry India
ANFIS	Adaptive Neuro Fuzzy Inference System
ANN	Automated Neural Networks
APES	Apparel Parks for Exports Scheme
APoP	Adjunct Professor of Practice
ARB	Arbitrageur
ASI	Annual Survey of Industries
ASSOCHAM	Associated Chambers of Commerce and Industry of India
ATIRA	Ahmedabad Textile Industry's Research Association
ATUFS	Amended Technology Upgradation Fund Scheme
BIS	Bureau of Indian Standards
BPJ	Bullet Proof Jacket
BTG	Business Transactions Group
BTRA	Bombay Textile Research Association
BTS	Bartlett's Test of Sphericity
CAG	Comptroller and Auditor General of India
CAGR	Compound annual growth rate
CAP	Creator Accelerator Program
CCEA	Cabinet Committee on Economic Affairs
CCI	Cotton Corporation of India
CE	Conformite Europeenne
CECRI	Central Electro Chemical Research Institute
CEO	Chief Executive Officer
CETP	Common Effluent Treatment Plant
CFC	Common Facility Centre
CFTRI	Central Food Technological Research Institute
CHCDS	Comprehensive Handicrafts Cluster Development Scheme
CHS	Cyber-human System
CII	Confederation of Indian Industry
CIPET	Central Institute of Petrochemicals Engineering & Technology

CLCSS	Credit Linked Capital Subsidy Scheme
CLRI	Central Leather Research Institute
CMIE	Centre for Monitoring Indian Economy
COC	Convention on Colorants
CoE	Centre of Excellence
COVID - 19	Corona Virus Disease 2019
CPCDS	Comprehensive Powerloom Cluster Development Scheme
CPI	Consumer Price Index
CPS	Cyber-physical System
Cr	Crore
CRISIL	Credit Rating Information Services of India Limited
CSB	Central Silk Board
CSIR	Council of Scientific & Industrial Research
CSR	Corporate Social Responsibility
CUTS	Consumer Unity and Trust Society
DASI	Data Acquisition Survey Instrument
DASI - V4	Data Acquisition Survey Instrument Version 4
DBT	Department of Biotechnology
DC	Development Commissioner
DHI	Department of Heavy Industries
DISK	Data Information Statistics and Knowledge
DKTE	Dattajirao Kadam Technical Education Society
DMAI	Dyestuffs Manufacturers Association of India
DPIIT	Department for Promotion of Industry and Internal Trade
DRDO	Defense Research and Development Organization
DSIR	Department of Scientific & Industrial Research
DST	Department of Science & Technology
DUI	Doing, Using and Interacting
EDII	Entrepreneurship Development Institute of India
EMPEA	Emerging Market Private Equity Association
EN	European Standard
ERP	Enterprise Resource Planning
ESG	Environmental, Social and Governance
EU	European Union
EY	Ernst & Young
FAPCCI	Federation of Andhra Pradesh Chambers of Commerce and Industry
FDI	Foreign Direct Investment
FFS	Fund of Funds for Start-ups
FI	Financial Institution
FIC	Focus Incubation Centres
FICCI	Federation of Indian Chambers of Commerce and Industry
FIC-ISID	Facility for International Cooperation for Inclusive & Sustainable Industrial Development
FPS	Focus Product Scheme
FTCCI	Federation of Telangana Chambers of Commerce and Industry
GDP	Gross Domestic Product

GFR	General Financial Rules
GI	Geographical Indications
GoI	Government of India
GOTS	Global Organic Textile Standard
GOV	Government
GRS	Global Recycle Standard
GST	Goods and Service Tax
GVA	Gross Value-Added
GVC	Global Value Chain
HAL	Hindustan Aeronautics Ld
HOF	Hochschule Hof, University of Applied Sciences
IAN	Indian Angel Network
IBEF	India Brand Equity Foundation
ICC	Indian Chamber of Commerce
ICT	Information and Communication Technology
IDA	Industrial Dispute Act
IFCI	Industrial Finance Corporation of India
IICD	Indian Institute of Crafts & Design
IIFPT	Indian Institute of Food Processing Technology
IIHT	Indian Institute of Handloom Technology
IIM	Indian Institute of Management
IIoT	Industrial Internet of Things
IISc	Indian Institute of Science
IIT	Indian Institute of Technology
IJIRA	Indian Jute Industries Research Association
IND	Industry
InduTECH	Industrial Textiles
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
ISDSI	Integrated Scheme for Development of Silk Industry
ISO	International Organization for Standardization
ISRO	Indian Space Research Organization
ISTC	Institutions Supporting Technical Changes
IT	Information Technology
ITAMMA	Indian Textile Accessories and Machinery Manufacture Association
ITASSI	Indian Textiles and Apparel Sectorial System of Innovation
IVP	Innovation Voucher Program
IWDP	Integrated Wool Development Programme
JPM	Jute Packaging Material
JUTE-IACRE	Improved Cultivation and Advanced Retting Exercise for Jute

K-DISC	Kerala Development Innovation Strategic Council
KBI	Knowledge-Based Institution
KPMG	Klynveld Peat Marwick Goerdeler
KMO	Kaiser-Meyer-Olkin
KPI	Key Performance Indicator
LDCOE	Lalbhai Dalpatbhai College of Engineering
LWE	Left Wing Extremism
MCCI	Madras Chamber of Commerce and Industry
MEITY	Ministry of Electronics and Information Technology
MSME	Medium, Small and Micro Enterprises
MANTRA	Man Made Textiles Research Association
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MSP	Minimum Support Price
MT	Metric Tonne
MMF	Man Made Fibre
MITRA	Mega Investment Textiles Parks
MoU	Memorandum of Understanding
MSDE	Ministry of Skill Development and Entrepreneurship
N95	Non-Oil Resistant 95%
NAAC	National Assessment and Accreditation Council (NAAC)
NABARD	National Bank for Agriculture and Rural Development
NAP	National Adaptation Plan
NDA	Non-Disclosure Agreement
NEP	National Education Policy
NER	North Eastern Region
NHDC	National Handloom Development Corporation
NHDP	National Handloom Development Programme
NIC	National Industrial Classification
NID	National Institute of Design
NIFT	National Institute of Fashion Technology
NIFT-TEA	National Institute of Fashion Technology – Tirupur Exporters Association
NIPAM	National Intellectual Property Awareness Mission
NIRF	National Institutional Ranking Framework
NIScPR	National Institute of Science Communication and Policy Research
NITI	National Institution for Transforming India
NITRA	Northern India Textile Research Association
NMCC	National Manufacturing Competitiveness Council
NMIS	National Manufacturing Innovation Survey
NSDC	National Skill Development Corporation
NSQF	National Skills Qualifications Framework
NTP	National Textile Policy
NTTM	National Technical Textiles Mission
OBM	Own Brand Manufacturing
OECD	Organization for Economic Co-Operation and Development

PCRA	Petroleum Conservation Research Association
PCSO	Production Control cum Supply Order
PE	Private Equity
PHDCCI	Progress, Harmony, Development Chamber of Commerce & Industry
PIB	Press Bureau of India
PLC	Programmable Logic Controller
PLI	Production Linked Incentive
PoP	Professor of Practice
PPE	Personal Protection Equipment
PSGCOE	Sri P. S. Govindasamy Naidu College of Engineering
QCS	Quality Certification System
R&D	Research and Development
RBI	Reserve Bank of India
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
RI	Research Institution
RMSS	Raw Material Supply Scheme
RoDTEP	Remission of Duties and Taxes on Exported Products
RoSCTL	Rebate of State and Central taxes and Levies
RPL	Recognition of Prior Learning
RR-TUFS	Revised Restructured Technology Upgradation Fund Scheme
RTC	Repository - Indian Textiles and Crafts
RTUFS	Restructured Technology Upgradation Fund
S&T	Science & Technology
SASMIRA	Synthetic & Art Silk Mills Research Association
SBI	State Bank of India
SBIIT	State Bank Institute of Innovation & Technology
SC	Scheduled Caste
SCBTS	Scheme for Capacity Building in Textile Sector
SEBI	Securities and Exchange Board of India
SEZ	Special Economic Zone
SGDTT	Scheme for Growth and Development of Technical Textiles
SGS	Societe Generale de Surveillance
SI	System of Innovation
SIDBI	Small Industries Development Bank of India
SITEX	Surat International Textile Expo
SITP	Scheme for Integrated Textile Parks
SITRA	South India Textile Research Association
SITRUST	Siemens Global Skill Centre for Occupational Safety
SKF	Svenska Kullagerfabriken
SLBC	State Level Bankers' Committee
SME	Small and Micro Enterprises
SMITA	Smart Materials and Innovative Textile Applications
SPA	State Procurement Agency
SSI	Sectorial System of Innovation
ST	Scheduled Tribe
STEP	Science and Technology Entrepreneur's Park

STI	Science, Technology and Innovation
STRIVE	Strengthening for Industrial Value Enhancement
SVCL	SIDBI Venture Capital Fund Ltd.
TCIDS	Textile Centre Infrastructure Development Scheme
TCL	Troop Comforts Limited
TH	Triple Helix
TMTT	Technology Mission on Technical Textiles
TNESSF	Tamil Nadu Emerging Sector Seed Fund
TRA	Technical Research Association
TRIZ	Theory of Inventive Problem Solving
TSInC	Textile Sectorial Innovation Council
TSSC	Textile Sector Skill Council
TUFS	Technology Upgradation Fund Scheme
TVE	Total Variance Explained
TVS	Thirukkurungudi Vengaram Sundram
UID	Unique Identification Number
UK	United Kingdom
UNCITRAL	United Nations Commission on International Trade Law
UNIDO	United Nations Industrial Development Organization
US	United States
USD	United States Dollar
USTTAD	Upgrading The Skills and Training in Traditional Arts/ Crafts for Development
UT	Union Territory
VC	Venture Capital
WIPRO	Western India Products
WOS	Wholly Owned Subsidiaries
WRA	Wool Research Association
WTO	World Trade Organization
YOY	Year-Over-Year
YSS	Yarn Supply Scheme
ZED	Zero Defect Zero Effect
ZDHC	Zero Discharge of Hazardous Chemicals

Conversion factor

1 Crore = 10 millions
1 Lakh = 100,000

Acknowledgements

The ITASSI Survey and Report would not have been possible without the close collaboration of key personnel from the Government of India (GoI), Department of Science and Technology, namely: Dr. Akhilesh Gupta, Senior Advisor, DST; and Mr. Marco Kamiya, Chief of Division of Digital Transformation and AI Strategies (DAS), United Nations Industrial Development Organization (UNIDO). Profound expressions of appreciation and special gratitude are extended to members of the Technical Advisory Committee, Dr. J. S. Juneja, Dr. Pradosh Nath, Dr. Aravind Chinchure, Dr. Rabindra Panigrahy, Dr. B Chagun Basha, Mr. P. K. Arya, and Dr. René Van Berkel, for their guidance during the project.

The crucial contributions of the Federation of Andhra Pradesh Chambers of Commerce and Industry (FAPCCI), Federation of Telangana Chambers of Commerce and Industry (FTCCI), India SME Forum, Madras Chamber of Commerce and Industries (MCCI), and the PHD Chamber of Commerce and Industry (PHDCCI) have been invaluable in terms of coordinating access and respondent participation in the survey.

Special thanks are extended to Dr. Sujit Bhattacharya, Dr. Debarchan Powali, Dr. Samiksha Sikarwar, CSIR-National Institute of Science Communication and Policy Research (CSIR-NIScPR); Dr. Arindam Basu, Northern India Textile Research Association (NITRA); Ms. Deepali Plawat, Ahmedabad Textile Industry's Research Association (ATIRA); Mr. N.D. Mhatre, Indian Textiles Accessories & Machinery Manufacturers (ITAMMA); Mr. S. Periasamy, NIFT TEA - Incubation Centre for Textiles & Apparels; and Dr. Toolika Gupta, Indian Institute of Crafts & Design (IICD) for their participation in the analysis workshop, provision of substantive inputs and the peer review of the results.

The data analysis presented in this report has been performed by Dr. Ritin Koria, Project Specialist for Innovation, UNIDO, Ms. Christi Thomas, Project Associate, UNIDO, and Mr. Pratik Dake, Project Assistant, UNIDO.

Technical chapters of the report have been authored by Dr K Chandra Shekar Consultant Kerala Development Innovation Strategic Council (K-DISC) Government of Kerala; Prof. Husain Kanchwala and Mr. Abhimanyu Pratap Singh, Indian Institute of Technology, Delhi; Dr. Ritin Koria, Ms. Sirjjan Preet, Ms. Christi Thomas and Ms. Reshmi Vasudevan, UNIDO.

The following enumerators provided excellent and invaluable support in the field, in India, for operationalising the survey and data acquisition and logistics: Mr. A.R. Vijayaraghavan, Ms. Adwitiya Ghosh, Ms. Aishwarya Phagiwala, Mr. Akash Chandrashekhar Lohi, Mr. Ankit Misra, Ms. Archana Rana, Ms. Arushi Jain, Mr. Binayak Prasad, Mr. Digvijay Uddhav Patil, Ms. Ekta Sinha, Mr. Faraaz Syed, Ms. Gowsia Saleem, Ms. Janhavi Ujjain, Ms. Kajoree Chetia, Mr. Kaushik Kumar Kundgulawar, Ms. Latika Sahni, Ms. Manaswini Ghosh, Ms. Mrinalini Jha, Ms. Nida Shahid, Mr. Pratik Dake, Dr. Preeti Lohani, Ms. Purnima Aggarwal, Mr. Saatvik Kaushik, Ms. Shagun Maheshwari, Ms. Sonali Hansda, Ms. Umang Vats and Mr. Vivek Deshwal.

Appreciation is also extended to Mr. Tomoyoshi Koume, Industrial Development Officer, UNIDO, for overseeing the overall project, Ms. Reshmi Vasudevan, National Programme Project Coordinator, UNIDO, Ms. Sirjjan Preet, Regional Project Coordinator, UNIDO and Mr. Kaushik Kumar Kundgulwar, Project Associate, UNIDO, whose efficient administrative and logistical support made the project execution all the more effective.

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

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 with domestic companies becoming an integral part of global supply chains. The goal of crafting a US $5 trillion economy by 2026-27 and India's aspiration to become a global economic powerhouse will be based on the foundation of a robust industrial sector and its innovative performance. India can leverage its strong Information Technology (IT) sector and drive supply chain efficiencies and productivity growth through deploying IT use at scale. By harnessing its soft power advantages it can catalyse a manufacturing revolution enabling India to become a global manufacturing superpower.

In order to facilitate an industrial revolution of this scale the Indian government needs to formulate a comprehensive vision for industrial development and execute it through the implementation of coherent and effective policy. The unprecedented disruptions of societies and economies caused by the COVID-19 pandemic have emphasised the need to take immediate action. In recent years, the Government of India (GoI) has launched special initiatives such as Production Linked Incentive (PLI) schemes to bolster India's industrial capabilities and technological innovation in 14 key sectors, while creating and nurturing global champions capable of producing for the world. The PLI scheme is a time bound initiative with a clear mandate of focusing on critical sectors that can attract maximum investments and scale rapidly to provide the maximum returns in terms of higher productivity, employment and exports. This scheme is also designed to identify and support adoption of the Fourth Industrial Revolution (4IR) technologies that are opening new avenues of opportunity for advancing economic competitiveness, creating shared prosperity, safeguarding the environment, and strengthening knowledge and institutions.

One of the most futuristic segments of the textile industry that is currently receiving significant attention is technical textiles, which are used across a range of industries and applications. The Ministry of Textiles' "National Technical Textiles Mission" aims to position India as a global leader in technical textiles through the promotion of research, innovation and development activities in this segment along with the proliferation of knowledge gained through these activities.

With knowledge emerging as a critical resource, better management and flow of knowledge 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.

The growth of the Indian textiles and apparel sector lies in the utilisation of 4IR technologies and knowledge production, the narrowing of technology and skill gaps, particularly in speciality fibres and sustainable textile segments, and in the interactions and contributions of technology and segment experts, scientists and academicians in this sector. It also needs clear and targeted policy, enabling the effective allocation of resources in order to transform India into a global textiles and apparel manufacturing hub.

The "Indian Textiles & Apparel Sectorial System of Innovation (ITASSI) 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 measurement through this survey enables the provision of evidence to guide policy. Hence, the ITASSI Report is 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. Moreover, the policy analysis, implications arising from the analysis and the policy recommendations presented in the report offer a range of evidence-based policy choices to facilitate policy decisions related to the role of sectorial system actors in the formulation of new textile policy. 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 textiles & apparel 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 to achieve national targets and goals effectively.

Executive Summary

This report, titled the "Indian Textiles & Apparel Sectorial System of Innovation (ITASSI) – Measurement, Analysis, and Policy Recommendations" surveys innovation and innovativeness in the textiles 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 (DST), Government of India (GoI).

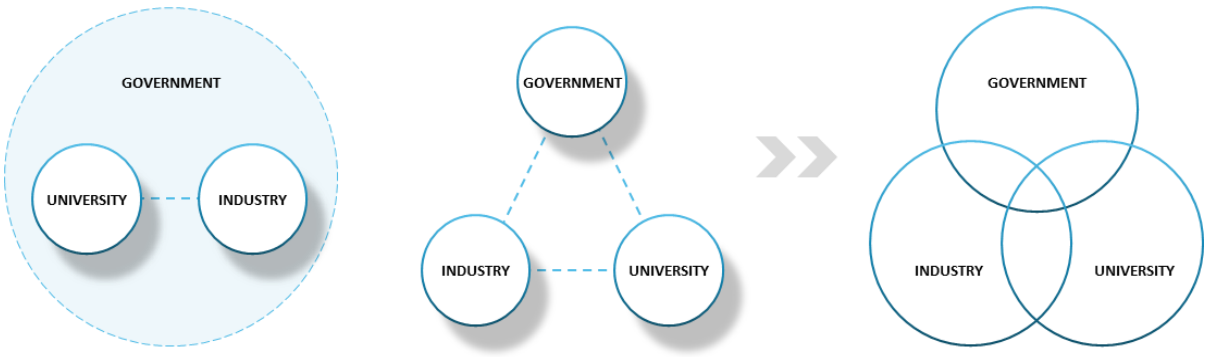
The report has been compiled for the GoI to inform innovation policy and improve innovation practices within the sector. Furthermore, it aims to facilitate coherent delivery of innovation policy and the establishment of a long-term policy monitoring and management capability for the sector.

Although there are many significant challenges identified, the 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 ITASSI. It provides an accurate visualisation of the connectivity between the core actors of the ITASSI, 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 ITASSI in terms of examining 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 textiles sector, our assessment is that the ITASSI falls into the category of a Triple Helix (TH) Type II, as per the traditional framing of the TH model. TH-Type I can be considered to be statist, and although the three spheres of the actors are strongly institutionally defined they work in isolation leading to the subsequent isolation of local technological knowledge. TH Type II refers to mechanisms of communication between the actors that are strongly influenced by the market and technological innovations. In this case, the point of control is at the interfaces and consequently new codes of communication are developed. The role of the government is primarily to limit cases of market failure. The TH Type II can be considered a 'laissez-faire' model of interaction in which actors are expected to act competitively rather than cooperatively with each other.

FIGURE 1: Triple Helix types



TH TYPE I TH TYPE II TH TYPE III

Consequently, there is the need to foster linkages between crucial actors of the ITASSI, particularly for the use and application of joint research, skills orientation, and development, as well as access to finance.

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

- Knowledge exchange between industry actors in order to make them more collaborative rather than competitive which is particularly important in the area of new technology adoption.
- Industry linkages with the knowledgebase in order to generate the requisite skills for the sector. This can be supported through structured placement programmes.
- Joint applied research between industry and the knowledgebase.
- Knowledge exchange and dissemination as well as joint research between knowledge-based institutions (KBIs), particularly in applied areas.
- KBIs seconding industry experts as faculty to foster practical knowledge exchange.
- Inter-governmental communication and knowledge sharing on the technical applications and uses of textiles.
- Intermediaries should better communicate industry needs to KBIs.
- Government to better disseminate information on funds amongst industry players, in particular MSMEs.
- Knowledge dissemination between arbitrageurs on the technological aspects of the textiles sector, particularly high-tech applications; and
- Increased access of funds for KBIs particularly for the process of ideation to market.

Secondly, the analysis highlights that relationships between actors in the ITASSI are imbalanced in that there is an unequal level of exchange between two actors 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 unfavourable to meaningful participation. Consequently, '**Industry 4.0**', '**ICT Knowledge and Flows**', '**Knowledge Stocks and Function**', '**Market Function**' and '**Human Capital**' emerge as the underlying barriers to innovation within the ITASSI.

From the perspective of '**Industry 4.0**', the associated variables are: 'Lack of understanding of I4.0 technologies', 'Cost of I4.0 technologies', 'Lack of access to I4.0 technologies' and 'Lack of infrastructure for I4.0''. In real terms, the challenges in adoption of I4.0 in the Indian textiles sector are multi-faceted. 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. Such capabilities are hard to be found in a single technology provider, especially in the case of small and micro enterprises.

The primary challenges associated with I4.0 adoption by the Indian textile and garments sector are lack of trained staff; lack of understanding and commitment by senior management; limited government support; poor research and development; high implementation costs; and fear of failure.The first step towards successful 4IR implementation for the Indian textiles sector is a clear understanding of I4.0 technologies and articulation of the value, goals and needs of I4.0 technologies among many firms.

'**ICT Knowledge and Flows**' as a barrier to innovation underscores that Increased ICT adoption reduces information asymmetry and information flows are vital for the innovation process. The variables that are associated with 'ICT knowledge and flows' as a barrier are: 'ICT capacity', 'Rate of access to ICT' and 'Brain drain'. Although ICT penetration is good across India, sectors such as milk and dairy are still seeing a transformational change with many facilities still using outdated dairy automation systems. The Indian textiles sector is not unfamiliar with the ongoing digital push and there is a growing acceptance of digital innovations and technologies becoming a part and parcel of the Indian textiles sector.

Specific issues faced by the sector include the vital need to reduce the digital skills gap between the digitally skilled and unskilled through imparting skill-intensive, particularly digital skill-intensive training to existent textile workers. This is imperative to prevent imminent job losses. Similarly, there is an urgent need to close the digital urban–rural divide and build ICT access through the provision of access to digital infrastructure.

'**Knowledge Stocks and Function**' as a barrier is associated with the variables 'Lack of information (knowledge gap)', 'Lack of technology (technology gap)' and 'Lack of legal framework' . In the case of weaving, most of the infrastructure of the domestic machinery manufacturers is outdated. This has partly been due to uncertain demand, the lack of incentives for modernisation and high import duties on machinery which act as deterrents for upgrading and modernisation. In addition, despite India being a leader in the field of software and

information technology, this has not been transmitted to weaving. There is a clear need for current technologies to incorporate more electronics and control hardware and software, which is imperative to boosting productivity and quality. To compound this there is an unprecedented demand for trained technicians. However, most students graduating out of engineering colleges and institutes migrate to more lucrative sectors thus leaving the textiles sector with a skills deficit.

'**Market Function**' can be described by rapid changes in technologies, changes in market structure, the instability of market demand, intense fluctuations in supply of materials, and the probability of market shocks. Its emergence as a barrier shows its importance in driving innovation through demanding customers and innovative customers, as well as distinct 'rules of the game'. The variables associated with this barrier are 'Lack of demanding customers', 'Lack of innovative customers' and 'Lack of explicit policy support system (government)'. Volatility and unpredictability characterise market dynamism, therefore a high level of market dynamics restricts the ability to distinguish the market boundaries, develop clear successful business models, and identify market participants such as competitors, customers, and suppliers and their respective needs. Consequently, this leads to external uncertainty thus making it more difficult to predict future market situations, plan and organise their resources, and respond with their own knowledge and related processes. This has been made evident during the recent pandemic. In order to adapt and survive, firms are required to remain agile and to improve and modify their products and services with innovations continuously to meet customers' needs. Considering the above, in order to promote innovation, a dynamic market is required, and regulations which encourage market dynamism, innovation and competitiveness improve economic performance.

'**Human Capital**' as a barrier has the variables 'Lack of technically trained manpower' and 'Quality of technically trained manpower' associated with it. Human capital is a collective resource that emerges from the knowledge, skills, and abilities of employees. For the Indian textiles and apparel sector, the quality of technically trained manpower particularly in the areas of Industry 4.0 and ICT is a challenge. To compound this, a general observation for the textiles sector is that it is not attractive to new graduates. Salaries are not competitive when compared to sectors like ICT, banking and finance and thus there is a dearth of skilled human capital.

In a post pandemic era, a management system for the sector based on old rules a hierarchy oriented around uniformity, bureaucracy, and control will no longer be effective. There is a global shift towards increased flexibility, responsiveness, creativity, adaptabilty, and lack of fragility. These are considerations that need to be carefully addressed in bolstering the Indian textiles and apparel sector.

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 is 'Explicit firm innovation policy support'. This is reflective of the barriers reported under 'Market Function'. There is a clear need for better articulation of policy, reducing complexity, to make it more accessible at the level of MSMEs.

In addition to this system-wide perspective, 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 there are very few externalities that emanate from the public goods of funding and support, and innovation inputs need to be better translated into innovation outputs. The present public infrastructure needs to be strengthened to create a fabric of vibrant linkages that foster knowledge and information exchange and support innovation. What is required is a widely accepted conducive environment for the textiles sector in which organizational rigidities are overcome.

The ITASSI 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 ITASSI 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].

[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 organisation 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 behaviour 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).

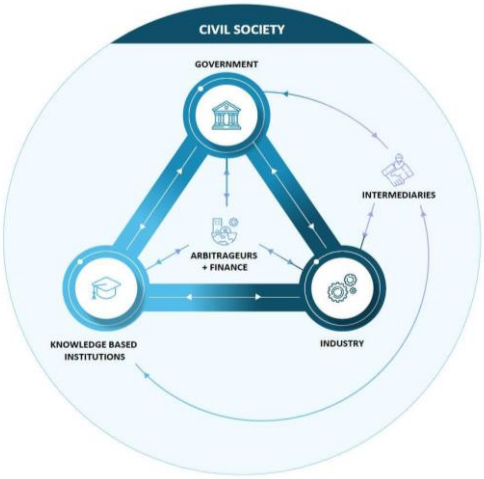
By using the systems framework as a tool for analysis, policy makers can identify: (1) where systemic failures occur; and (2) which actors should be addressed to make change possible. Most problems in the innovation system will not be uni-dimensional but will consist of a complex mixture of causes and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

Furthermore, 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

Our framework for analysis of the ITASSI 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 textiles and apparel sector. These functions span across the innovation value chain, namely: knowledge generation and transfer; technology development, acquisition, and transfer; product development; testing services; 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: Examples of core actor, arbitrageur and intermediary organizations by function

Function	Knowledge based institutions	Government	Intermediaries	Arbitrageurs
Technology Development	• University-enterprise joint research centre • Science Park • IIT Delhi • LD College of Engg • NIFT / NID • PSG College •	• Ministry of Textiles • Textile Commissioners Office • Industries Commissionerate Office (State Government) • Department of Science & Technology • Ministry of Heavy Industries	• BTRA • NITRA • SITRA • ATIRA • SASMIRA • MANTRA • WRA • IJIRA	• Indian Angel Investors • Native lead foundation
Technology Transfer	• Science Park • University-enterprise joint research centre • IIT Delhi • LD College of Engg • NIFT / NID • PSG College	• Ministry of Textiles • Textile Commissioners Office • Industries Commissionerate Office (State Government) • Department of Science & Technology • Ministry of Heavy Industries	• BTRA • NITRA • SITRA • ATIRA • SASMIRA • MANTRA • WRA • IJIRA	
Technology Acquisition **R&D**	• MSME, IITs • NIFTS • NID • IICD • IIT Delhi • IIT Mumbai • IIT Chennai • IIT Guwahati	MSME • Cotton Textile Corporation of India • Ministry of Textiles • Textile Commissioners Office • Industries Commissionerate Office (State Government) • Department of Science & Technology • Ministry of Heavy Industries	• BTRA • NITRA • SITRA • MANTRA • ATIRA • SASMIRA • WRA • IJIRA	
Knowledge Transfer	• NIFT • NID • IICD • IIT Delhi • LD College of Engg • PSG College	• Ministry of Textiles • Cotton Corporation of India • Textile Commissioners Office • Industries Commissionerate Office (State Government) • Department of Science & Technology • Ministry of Heavy Industries	• ITAMMA • ATIRA • BTRA • NITRA • SITRA • SASMIRA • MANTRA • WRA • IJIRA	
IP Protection	• Science Park	• Patent offices	• Incubators - NIFT-TEA AIC	
Infrastructure Development	•	• Ministry of Textiles • Textile Commissioners Office • Industries Commissionerate Office (State Government) • Department of Science & Technology • Ministry of Heavy Industries	• BTRA • NITRA • SITRA • ATIRA • SASMIRA • MANTRA • WRA • IJIRA	
Product Development	• NIFTS • NID • IIT Delhi • IIT Mumbai • IIT Chennai • IIT Guwahati	• Cotton Textile Corporation of India • Ministry of Textiles • Textile Commissioners Office • Industries Commissionerate Office (State Government) • Department of Science & Technology • Ministry of Heavy Industries	• ATIRA • BTRA • NITRA • SITRA • SASMIRA • MANTRA • WRA • IJIRA	

Human Capital Development	• NIFT • NID • IIHT (Indian Institute of Handloom Technology) • IICD	• Department of Labour and Welfare • Ministry of Textiles • Textile Commissioners Office • Industries Commissionerate Office (State Government) • Department of Science & Technology • Ministry of Heavy Industries	• BTRA • NITRA • SITRA • ATIRA • SASMIRA • MANTRA • WRA • IJIRA	
Business Development	• PSG College of Engineering STEP • IIMs	• Mega Textile Park/Apparel Park • Textile Commissioners Office • Industries Commissionerate Office (State Government) • Department of Science & Technology	• NIFT - TEA Atal Incubation Centre • NID Design Incubation Centre • AIC Surati iLab - Gujarat	
Funding	• University-enterprise joint research centre	• Ministry of Textiles • Textile Commissioners Office • Industries Commissionerate Office (State Government) • Department of Science & Technology • Ministry of Heavy Industries	• BTRA • NITRA • SITRA • ATIRA • SASMIRA • MANTRA • WRA • IJIRA	
Agenda setting		• Ministry of Textiles • Textile Commissioners Office • Industries Commissionerate Office (State Government) • Department of Science & Technology • Ministry of Heavy Industries	• BTRA • NITRA • SITRA • ATIRA • SASMIRA • MANTRA • WRA • IJIRA	
Testing & certification services	• University-enterprise joint research centre	• Bureau of Indian Standards (BIS) • OKEX-TEX Certification • GOTS/GRS Certification • SGS Certifications Pvt. Ltd. • EN STANDARD • CE • ZDHC • REACH	• BTRA • NITRA • SITRA • ATIRA • SASMIRA • MANTRA • WRA • IJIRA • SGS Certifications Pvt. Ltd. • Intertek	

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 centre 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 Indian Textiles and Apparel Sectorial System of Innovation (ITASSI) 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 Textiles and Apparel Sectorial System of Innovation (ITASSI) Survey has been conducted to obtain a holistic view of the SSI as a basis for evidence-based innovation policy for the textiles and apparel sector; one 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 ITASSI 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 textiles and apparel 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 textiles and apparel sector.

Procedure:

Non-firm actors, namely GOV, KBI, ARB and INT were sampled on a convenience basis. A frame was prepared for the textile 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.

FIGURE: Firm size classification

Turnover	≤ 5 cr	Large	Medium	Small	Micro
	≤ 50 cr	Large	Medium	Small	Small
	≤ 250 cr	Large	Medium	Medium	Medium
	> 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 after the survey as:

- 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 57.72%, a firm response rate of 57.46% and non-firm response rate of 60.50%.
- 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

[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.

[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.

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 textile 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 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 ITASSI 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.

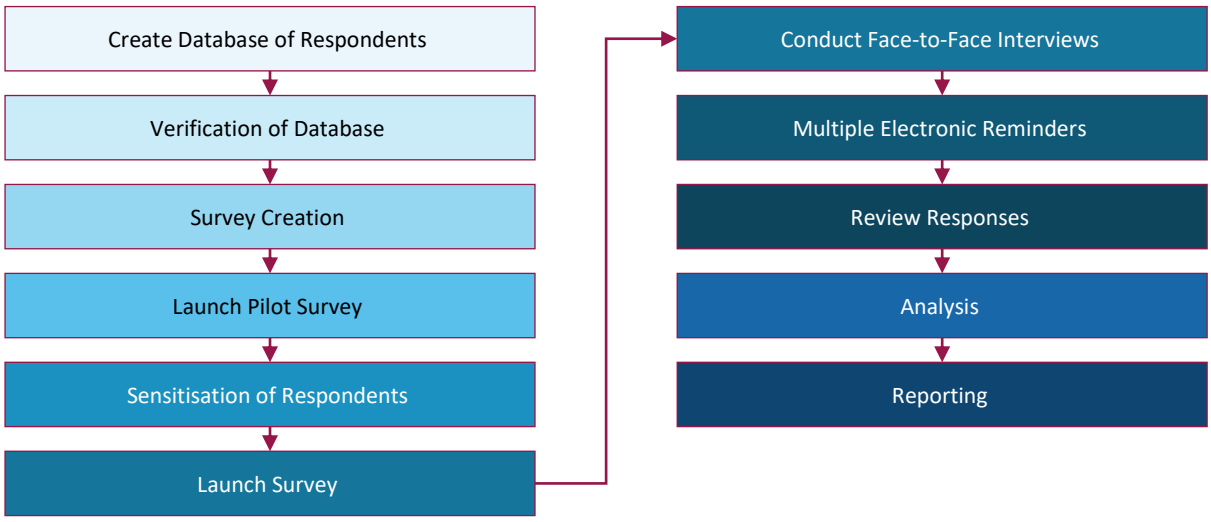
3.4 Survey Operationalisation

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 ITASSI 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 textiles and apparel 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.

Indian Textiles and Apparel Sector

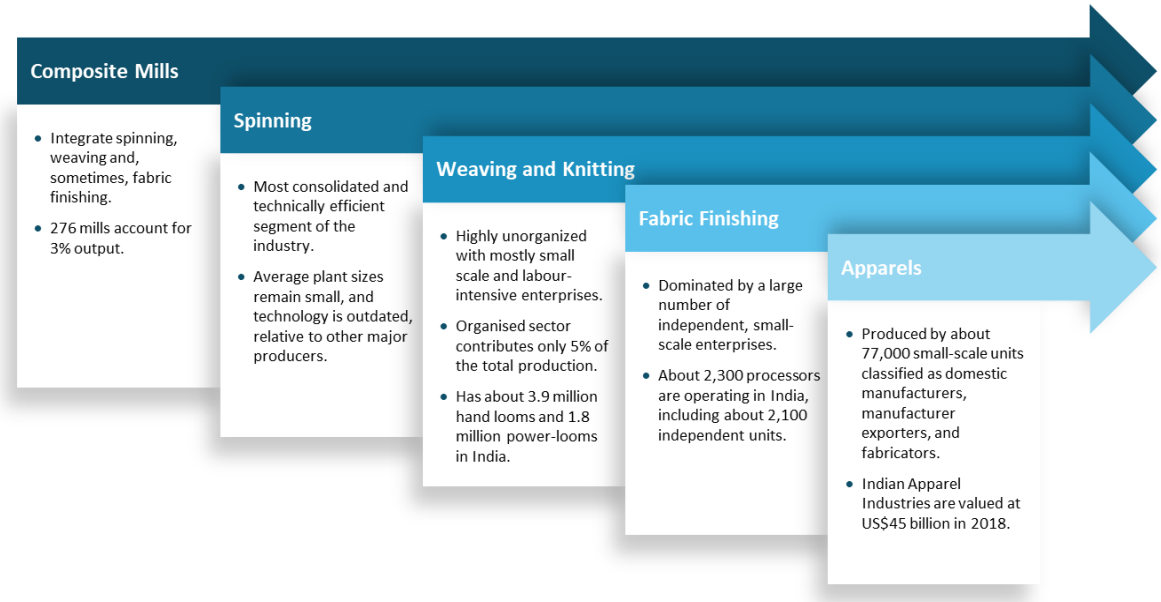
Indian Textiles and Apparel Sector

4.1 Indian Textiles and Apparel Sector: Structure and Dynamics

The Indian textiles and apparel industry is an important sector for India as India is the world's second-largest producer of textiles and garments. The country is also the fifth-largest exporter of textiles, spanning apparel, sports and outdoor, home and other technical textiles. India's export value is almost equal with Germany, Bangladesh, Vietnam, and Italy (ranking respectively 2nd, 3rd, 4th and 6th globally). The textiles sector alone accounts for 6.7% of the manufacturing value-added, 10.8% of manufacturing jobs and 6.6% of merchandise exports. The sector generated over 2% of India's gross domestic product and 12% of the country's export earnings [21]. Furthermore, the apparel sector accounts for 4.1% of merchandise exports and combined with leather and footwear respectively this equates to 2.6% of manufacturing value-added and 10.4% of manufacturing employment [22].The industry directly employs around 45 million workers, including 3.5 million handloom workers and indirectly a further estimated 60 million as (cotton) farmers and in its supply and associated service sectors.

The Indian textile and apparel industry is highly diversified with a wide range of segments ranging from traditional handloom, handicrafts, wool, and silk products to Ready Made Garments (RMG) and technical textiles, including sports and performance wear as well as home textiles, etc. The organised textile industry in India is characterised by the use of capital-intensive technology for the mass production of textile products and includes spinning, weaving, processing, and apparel manufacturing [23]. The defining feature of the Indian textiles and apparel industry is, however, the dominance of small-scale non-integrated spinning, weaving and knitting, fabric finishing, and apparel-making enterprises, as illustrated below [24]. Some 70 textile and garment clusters in five main regions (Andhra Pradesh, Gujarat, Haryana and Punjab, Maharashtra and Tamil Nadu) are responsible for 85% of textile and garment production in India.

FIGURE 4: Structure of the Indian textiles and apparel industry



[21] See: https://www.makeinindia.com/sector/textiles-and-garments
[22] See: https://iap.unido.org/country/IND
[23] See: https://www.investindia.gov.in/sector/textiles-apparel
[24] See: CRB (2022), Circular textile and apparel in India: policy intervention priorities and ideas, Centre for Responsible Business, New Delhi, India.

India is a major net exporter of textiles, the 6th largest globally[25], and enjoys a huge trade surplus. Its importance lies in its contribution to GDP, being 4%, and its contribution to the employment of 45 million people[26]. Cotton plays a major role in sustaining the livelihoods of 5.8 million farmers and an estimated 40-50 million others including its processing and trade. The jute industry provides direct employment to 0.37 million workers in organised mills and diversified units including the tertiary sector and allied activities, supporting the livelihoods of millions of farmers. The silk or sericulture industry, which has received funding from the convergence of various ministries (Ministry of Rural Development, Ministry of Textiles) and schemes ("Mahatma Gandhi National Rural Employment Guarantee Act" and "Silk Samagra") provides sustainable livelihoods to farmers and women of marginalised communities (in the states of Jharkhand, Odisha, West Bengal, Chhattisgarh, Maharashtra, Andhra Pradesh, Bihar and Assam) by way of 36,000 jobs. The silk industry supports the socio-economic development of a large agrarian population, providing employment to 9.4 million people in rural and semi-urban areas (Vishwanath, 2021). There is also a desire to make India a competitive and quality manufacturer/supplier of woollen products through optimising the sector.

India is the second largest producer, as well as consumer of textiles and garments after China. It exports textiles and handloom products to over 100 countries, with the USA, EU-27 and the UK comprising 47% of the country's textiles and apparel exports. In the financial year (FY) 2020-21, the share of textiles and apparel (including handicrafts) in the country's total exports stood at 11.4%. India has a 4% share in the world textiles and apparel market (FY 2020-21) and is presently the world's second largest producer of cotton textiles and garments after China.[27] India exports textiles and handloom products to over 100 countries and the USA, Bangladesh, UAE, China and UK accounting for 50% of these exports.[28] The industry provides direct and indirect employment and is a source of livelihood for millions of people including women and rural populations.

The uniqueness of this industry lies in its strength in both the handwoven sector, as well as in the capital-intensive mills sector. The mill sector is the second largest in the world. Traditional sectors like handloom, handicrafts and small-scale powerloom units are the biggest source of employment in rural and semi-urban areas. The sector aligns well with the key mandates of government schemes such as "Make in India" and "Skill India", as well as those that promote women empowerment and the employment of rural youth.

In light of the goals of inclusive and participatory development, the government has a central focus on building best-in-class manufacturing infrastructure, achieving technology upgradation through fostering innovation, and enhancing skills and traditional strengths in the textiles sector.

Cotton

In terms of raw material support, cotton is the most important cash crop, often referred to as "white gold" due to its economic value, as it accounts for around 25% of global fibre production. The proportion of cotton in India's raw material consumption basket of the textile industry is 60%. During FY 2020-21, India's productivity was around 460kg/ha and the consumption was 30 million bales (of 170kg each) per year. The country has therefore emerged as one of the largest producers, consumers, and exporters of cotton in the world. Cotton is one of the largest contributors to India's net foreign exchange by way of exports in the form of raw cotton, intermediate products such as yarn and fabrics to ultimate finished products like garments, made ups and knitwear. It plays a major role in sustaining the livelihoods of an estimated 5.8 million cotton farmers and around 50-80 million people engaged in cotton processing and trade. To support the industry, the government announced a minimum support price (MSP) for two basic staple groups i.e., medium staple and long staple cotton. In the event of the prevailing seed cotton price touching the MSP level, the nodal agency for managing the operations is the Cotton Corporation of India (CCI). The procurement of cotton by CCI during FY 2020-21 was 9.189 million bales (approximately 30% of production).

Jute

Jute is one the major industries in the north-east and eastern regions, particularly West Bengal, Assam, Bihar, Odisha and Andhra Pradesh. According to estimates, the industry provides direct employment to 0.37 million workers in organised mills and diversified units including the tertiary sector and allied activities, supporting the livelihoods of millions of farmers. The Government of India supports the industry, not only through MSP operations by the Jute Corporation of India but also through enforcing the direct packaging of jute sacking (INR 7,584 crore annually) for food grains under the compulsory legislation[29]. This is a

[25] Annual Report of the Ministry of Textiles (2021-22):http://texmin.nic.in/sites/default/files/AR_Ministry_of_Textiles_%202021-22_Eng.pdf
[26] Annual Report of the Textiles Ministry, 2014-15
[27] Sourced from: https://www.statista.com/statistics/263055/cotton-production-worldwide-by-top-countries/
[28] Sourced from: https://commerce.gov.in/about-us/divisions/export-products-division/ep-textile/
[29] Annual Report of the Ministry of Textiles (2021-22): http://texmin.nic.in/sites/default/files/AR_Ministry_of_Textiles_%202021-22_Eng.pdf

major support to jute mill workers and jute farmers. Additionally, a jute sacking supply management and requisition tool "JUTESMART app" has been developed and implemented since 1st November 2016. It currently indents around 1484.2 million bales worth INR 42,215 crore (December 2021) by State Procurement Agencies (SPA) from Punjab, Haryana, Odisha, Andhra Pradesh, Telangana, Madhya Pradesh, West Bengal, Bihar, etc. Production Control cum Supply Order's (PCSO) have been placed for these bales for the jute mills located in 6 states of local governments from several jute mills involving various intermediaries. Another initiative, "JUTE-IACRE" was launched to increase farmer incomes by at least 50% through the promotion of certified seeds, better agronomic practices and the use of microbial re-using of jute plants. These schemes are implemented by the National Jute Board, which is a statutory body and have shown tremendous promise.

Silk

Producing 33,770 metric tonnes annually, India is the second largest producer of silk in the world, after China, and the largest consumer. India is the only country which produces all varieties of silk including Mulberry, Tropical Tussar, Oak Tussar, Muga and Eri silk. The sericulture industry has wide employment potential but low capital requirements and provisions for remunerative employment to silk growers. Mulberry accounts for 70.76% (23896MT), Eri for 20.57% (6946 MT), Tussar 7.96% (2689MT) and Muga Silk at 0.71% (239 MT) of the total raw silk production. The bivoltine raw silk production declined by 3.2% to 6783 MT during FY 2020-21 from FY 2019-20. Similarly, Vanya silk, which includes Tussar, Eri and Muga silk, reduced by 14.3%, 3,6% and 0.8% respectively during FY 20-21 from FY 2019-20[30]. The silk production was impacted during the COVID-19 pandemic. "Silk Samagra", a Central Silk Board initiative, is an integrated scheme towards the development of the sericulture industry in the country that encompasses the maintenance of the basic silkworm seed farms supplying seeds to the states, R&D, training, transfer of technology, IT initiatives, market development, quality testing and certification, export, brand promotion, and upgradation (Vishwanath, 2021). Approximately 36,154 farmers including 2497 women farmers were supported to raise 1521 hectares (ha) of Tussar plantations in private wastelands; Under special projects, 14,227 commercial seed rearers produced 224 million reeling cocoons, and further expansion of the programme under the "National Rural Livelihood Mission" aims to include 35,000 women farmers.

Wool

For the growth of the wool sector, the Ministry of Textiles approved the rationalisation and continuance of the "Integrated Wool Development Programme", which was approved by the Standing Finance Committee in 2021 under the "Central Sector Scheme". One of its objectives is to make India a competitive and quality manufacturer/supplier of woollen products through technological interventions and optimising the different segments of the wool sector through:

Harmonising the wool supply chain and to enhance backward and forward linkages by increasing the raw wool procurement capacity of the state government.

- Creating facilities for linking the wool industry with wool producers.
- Providing a marketing platform to small woollen manufacturing through expos.
- Coverage of more sheep through machine shearing to improve quality.
- Improvement in the finished woollen products quality through establishing modern wool processing machines.
- Increase wool testing, bale forming facilities and providing tools for manufacturing woollen products.
- Utilisation of coarse wool, and use of wool in technical textiles through research and development.
- Skills development and capacity building for manufacturing handmade traditionally designed quality woollen products.
- Branding of pashmina and carpet grade wool.
- Development of pashmina wool sector in Himalayas.

In the section below on India's technological trajectory and technological upgradation, we shall discuss the nature of innovation under the "Amended Technology Upgradation Funds Scheme" and see how automation in its current format can help leapfrog into Industry 4.0 across textiles due to the nature of activities.

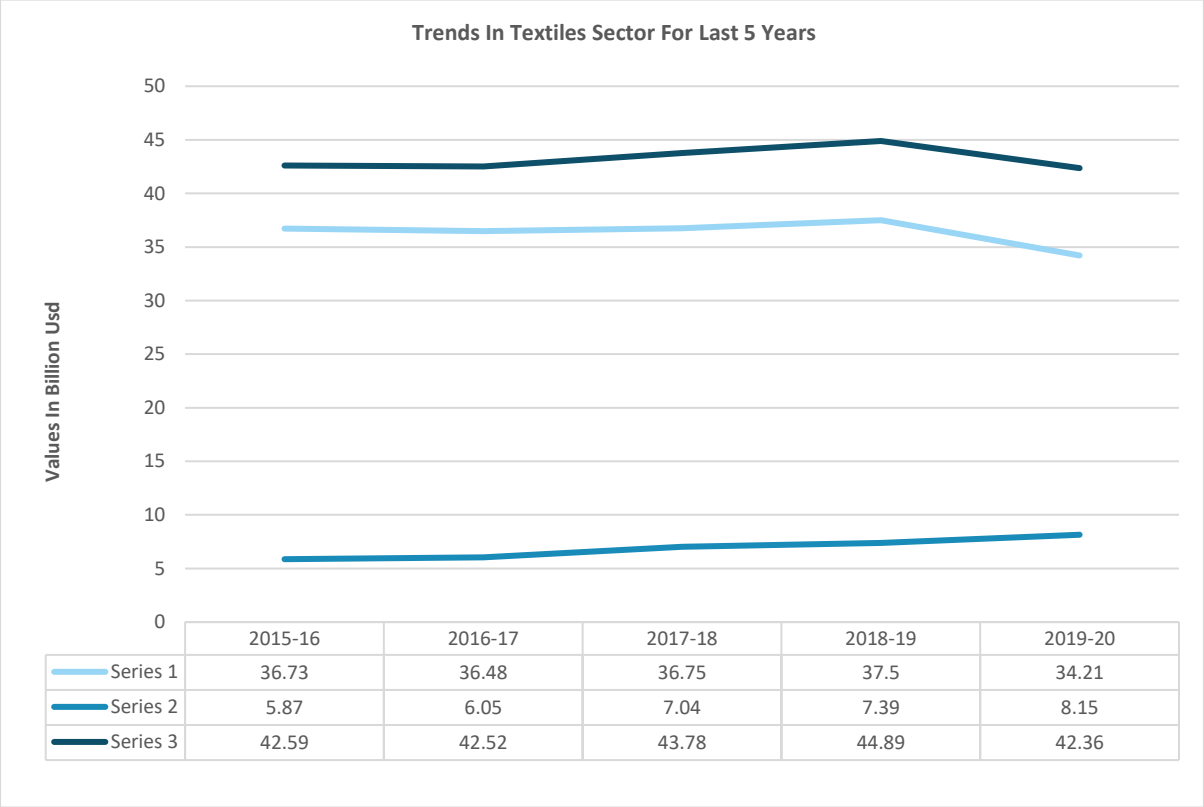
4.2 Recent Developments in the Textiles Sector in India

The government has put several efforts to expand market access of the sector through bilateral arrangements. The removal of procedural bottlenecks in exports was done through Foreign Trade Policy and other policy instruments

[30] Sharma, Deepesh. Just Agriculture. Sericulture: Importance and potential: https://justagriculture.in/files/newsletter/2022/january/075.pdf

to enable the expansion of market access. India's textile trade has witnessed a steady increase, since FY 2016-17, except for the FY 2019-20. The total textiles trade in FY 2019-20 stood at US$ 42.36 billion in comparison with US$ 44.89 billion in FY 2018-19. The export of textiles stood at US$ 34.21 billion, while the imports were at US$ 8.15 billion. The export of textiles witnessed a declining growth at a rate of (-) 8.74% whereas imports witnessed a growth rate of 10.33% during FY 2019-20. The share of textile exports in the export basket of India was 11.34% in FY 2019-20 (Department of Commerce, GoI[31]). Figure 5[32] shows the export and import figures for the last five years in US$ billion from FY 2015-16 to FY 2019-20.

FIGURE 5: India's textiles trade at a glance from 2015-16 to 2019-20 (in US$ billion)



	2015-16	2016-17	2017-18	2018-19	2019-20
Series 1	36.73	36.48	36.75	37.5	34.21
Series 2	5.87	6.05	7.04	7.39	8.15
Series 3	42.59	42.52	43.78	44.89	42.36

In 2021, India was the 6th largest exporter of textiles (by value) at US$ 16 billion with China in the 1st spot at US$ 176 billion and the European Union in the 2nd spot with US$ 151 billion (Statista, 2022). India's trade balance with China has been negative for a long time, due to restricted market access. Exploring alternative markets would require a product-wise comparison of the potential for exports[33].

In FY 2021-22, the export of cotton was US$ 17.2 billion with a 39% share, registering a growth of 54% and 67% during FY 2021-22 over FY 2020-21 and FY 2019-20, respectively[34]. India has recently achieved its highest ever export tally at US$ 44.4 billion in textiles and apparels, including handicrafts. Domestically, the textiles industry in India is distributed in clusters, mainly in Rajasthan, Gujarat, Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh (Sharma et al., 2018).

Composition and Distribution

A closer look at the technological trajectory in this fragmented and labour-intensive industrial sector reveals that the sector is divided into artisanal or handicrafts on the one hand and the powerloom mills sector on the other. The Indian textile industry comprises of:

- Traditional handloom sector with manually operated technology.

[31] Trade Statistics, Textiles Coordination Division, Export Products Division, Department of Commerce, Government of India: https://commerce.gov.in/about-us/divisions/export-products-division/ep-textile/

[32] Sourced from: Department of Commerce, Government of India.

[33] Statista. Leading Exporting countries of textile worldwide by value in 2020: https://www.statista.com/statistics/1054452/textile-apparel-goods-leading-exporters-worldwide/

[34] Sourced from: https://pib.gov.in/PressReleasePage.aspx?PRID=1829802

- Powerloom sector [35] which is a technologically improved form of handlooms (weaving only).
- Composite mill sector with its advanced technology.

The handloom sector is scattered across the country in villages. The powerloom sector is decentralised and scattered in and around some centres and the mill sector is well-organised and integrated to a large extent, a part of which is composed of spinning, weaving, and processing under a single roof. There was a change in fortunes when mass production on powerloom machines started. The household enterprise could not face this competition, due to the efficiency and quality that became achievable in the powerloom manufacturing sector, in comparison to the handloom sector. The advent of mills came at the right time, due to the demands of the environment. Soon they began supplying yarn to the handloom sector, as they sought to replace imports. This development improved the socio-economic status of the workers in the handloom sector, which employs 6.5 million workers that operate the 3.5 million looms, yet concerns remain in other clusters as studies reveal (Prathap and Naidu, 2015; Mishra and Mohapatra, 2019; Mohsin Khan, 2022). The handloom sector is beset with problems such as technological obsolescence, haphazard production systems, low productivity, inadequate working capital, conventional product ranges, weak marketing links, overall stagnation of production and sales and above all, competition from the powerloom and mill sectors. Indian textiles are a costly source of design in the world, drawn upon increasingly by textile designers and product designers. Currently, the income and living standards of the handloom weavers is very low. Therefore, the traditional textiles and handloom sectors are vying to find their niche within the industry. On account of their limitations, the emergence of powerlooms has taken place. Handlooms have cost and time of production disadvantages and mills are investment and technologically intensive (Chaterjee, 2015). Therefore, for speedy production in small and distant places, weavers started installing powerlooms as decentralised units. India has 1.9 million power mills that weave 19000 million metres of woven fabric annually, providing employment to more than 7 million workers[36]. The number of shuttleless looms has grown to 50,000, and 35,000 of these are working in the decentralised sector. These units are concentrated in the semi-urban and rural areas. Maharashtra has 1.2 million powerlooms, followed by Tamil Nadu with 443,983 powerlooms, and Gujarat with 323,400 powerlooms[37]. The distribution of powerlooms in this sector is as per Table 3[38] below. There is a marked dominance of powerlooms in the Indian textiles industry. However, this does not portray an accurate picture of technological advancement within the industry, which is discussed further below based on the statistics of individual cluster development, their employment, turnover and export potential.

[35] Textile Value Chain. Power Loom Cluster in India: https://textilevaluechain.in/in-depth-analysis/articles/textile-articles/power-loom-cluster-in-india/
[36] Ibid.
[37] Ibid.
[38] Ibid.

TABLE 3: Distribution of textile mills in the powerloom segment of the Indian textiles industry

S. No.	Name of the State/Union Territory	No. of Units	No. of Looms
1	Andhra Pradesh	11496	53251
2	Assam	264	2738
3	Bihar	1443	2894
4	Goa	18	122
5	Gujarat	32249	323400
6	Haryana	2713	12293
7	Himachal Pradesh	182	1461
8	Jammu & Kashmir	56	65
9	Karnataka	24586	81890
10	Kerala	673	2804
11	Madhya Pradesh	53043	133425
12	Maharashtra	284786	1280694
13	Orissa	792	3321
14	Punjab	3661	23620
15	Rajasthan	4036	34271
16	Tamil Nadu	86740	443983
17	Uttar Pradesh	25135	65993
18	West Bengal	1037	6195
19	Delhi	124	1102
20	Telangana	20	160
21	Chandigarh	32	560
22	Dadra & Nagar Haveli	29	684
23	Pondicherry	117	830
Total		**543232**	**2475756**

There were no initial records of the establishment of powerlooms in India. However, today there is greater data availability on the employment, turnover and exports undertaken by clusters. Table 4 below shows the cluster-wise employment, turnover, and export potential of powerlooms (Misra & Das Gupta, 2019). The functioning and problems associated with the powerloom industry are marked in the Malegaon district cluster in Maharashtra (Anjum and Thakor, 2011).

TABLE 4: Employment, turnover and export potential of powerloom mills in India

S. No	State	Name of the Cluster & Category	No. of Units	Employment Person/Family	Turnover Cr/Annum	Exports Cr/Annum
1	Andhra Pradesh	Nagari, Horizontal Guntur Warangal, Horizontal Sirsilla	 <1000 20000	24000 <1000 15000*	500 0-10 50-60	
2	Gujarat	Katol, Horizontal Surat Gandhinagar Chhatral	100-500 1000-10000	1000-10000 >10000	0-10 100-1000	M M
3	Haryana	Bhiwani Panipat	<100 5702	1000-10000 34892	100-1000 405.7	L
4	Karnataka	Beigaum Bangalore, Horizontal Gadag, Betgeri, Horizontal	 100-500	 <1000	10-100 100-1000	L
5	Kerala	Earnakulam Malappuram, Horizontal Palakkad Faizlure				M M M M
6	Madhya Pradesh	Burhanpur, Horizontal Jabalpur, Horizontal Ujjain	9890			

7	Maharashtra	Ichaikaranji, Horizontal Malegaon, Horizontal Madhavnagar, Horizontal	244 7500	100000	4900	
8	Orissa	Dhenkanal Ganjam, Horizontal Balasore, Horizontal		1000-10000 1000-10000	0-10 0-10	M M
9	Punjab	Amritsar, Horizontal	200	1500	400	50-60
10	Rajasthan	Kishangarth Horizontal Beawar Jaipur Bhilwara, Horizontal	400 60 25 159	5555 950 300-400	 24 50 45-50	
11	Tamil Nadu	Surampatti, Erode Kanur, Horizontal Bhavani	160	 160	8000	
12	Uttar Pradesh	Mau, Vertical Kanpur Gorakhpur, Vertical Jhansi Varanasi, Vertical Meerat	 300 27500 Looms	 3000	 300	 40
13	Bihar	Bhagalpur	1200	3000	800	
14	West Bengal	Nadha Ranaghat	500-10000	1000-10000	10-100	

The diversity of powerloom types demonstrates that there was no adoption of a single technological advancement over time. Although there is a diversity of powerloom types in India across clusters like rapier, air jet and projectile machines, etc., the overall lack of shuttleless powerlooms is a major impediment to modernisation in comparison to the USA, China, Europe, and Taiwan, etc. Modern looms are 15000 in number, whereas there is a predominant number of traditional looms. Technological obsolescence is a key barrier to value addition and meeting client specifications. The multiple challenges faced by the powerloom sector include: high power tariffs and the unreliable supply of power; a tendency of cost-cutting by entrepreneurs (including unethical practices such as labour exploitation, the unsuitable deployment of machinery and tax evasion); the family business nature of these units; a lack of awareness of the potential of technical textiles, the labour displacement likely to result from automation, and a lack of skilled labour to support technological upgradation. The potential of technical textiles emerges as a key opportunity within this overall context.

4.3 Technical Textiles and Growth Potential within the Indian Textiles Industry

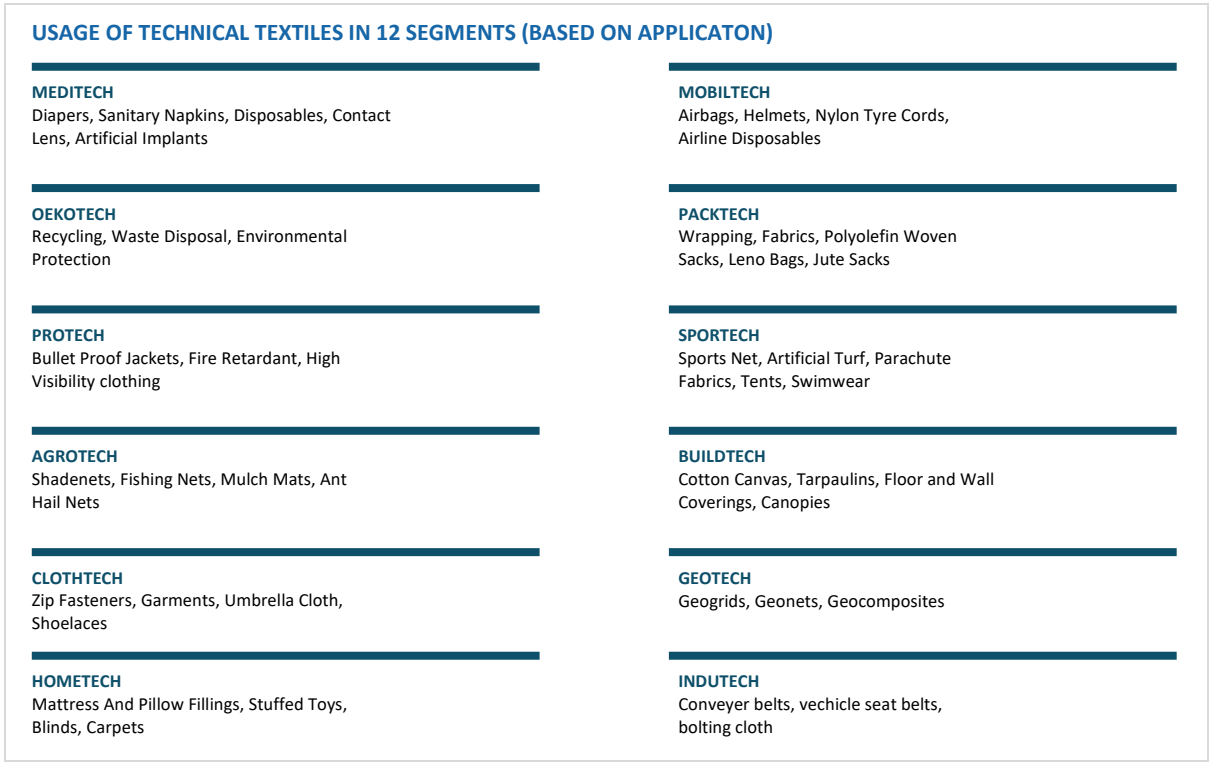
The technical textiles sector has branched out and has a diversified product profile in contrast to conventional handloom products. Their use is widespread across key end-use industries like healthcare, defense, automobile, and construction (referred to as the "technical textiles[39]" industry). India's strengths have already been defined in the traditional textiles and natural fibres sectors on a global platform. It is also the second largest producer of textiles in the world and is slowly, but steadily emerging as a key player in the technical textiles industry contributing to a market size of US$ 19 billion. India's leap towards modernisation and its overall manufacturing competitiveness are some of the key contributors to the growth of this segment (Sharma, Lakshmanan and Nayyar, 2020). Technical textiles account for 13% of India's market and contribute 0.7% to the country's GDP. There is however a huge demand potential as the consumption of technical textiles is still 5-10% in comparison to 30-70% in advanced countries. The "National Technical Textiles Mission" (NTTM) set up by the Prime Minister of India and Cabinet Committee on Economic Affairs (CCEA) seeks to increase the domestic market size of technical textiles to US$ 40-50 billion by 2024, through market development, market promotion, international technical collaborations, and investment promotion of manufacturing in India. Technical textiles is a sunrise sector and came further into prominence during the pandemic. From manufacturing zero personal protective equipment in March 2000 to producing 250,000 units per day in 60 days, India became the second largest manufacturer after China. In August 2020, the figure rose to 450,000 PPE kits each day[40]. Despite the economic downturn and slowdown, India has proved its ability to innovate and rise to the challenge with limited resources and time. There is a need for greater collaboration between government and industry in

[39] Technical textiles are engineered products with definite functionality. They are manufactured using natural as well as man-made fibres such as Nomex, Kevlar, Spandex, Twaron that exhibit enhanced functional properties such as higher tenacity, excellent insulation, improved thermal resistance.

[40] Lackshmanan, Remya and Nayyar, Mishika. Invest India. Personal Protective Equipment in India: An INR 7,000 Cr industry in the making: https://www.investindia.gov.in/siru/personal-protective-equipment-india-INR-7000-cr-industry-in-the-making

technical textiles as it is a high-value segment of the sector. The products find end-use application across multiple non-conventional textile industries such as healthcare, construction, aerospace, ports, defense, agriculture, etc. Taking cognisance of technological advancement, countries are aligning their industries to accommodate technical textiles. This shift is evident in India's textiles sector. The use of technical textiles in 12 segments based on use is shown in Figure 6 below (Lakshmanan and Nayyar, 2020).

FIGURE 6: Use of technical textiles across 12 segments



The pandemic had a deep impact on the sector, which transformed crisis into opportunity. According to a baseline study conducted in 2020 by the Ministry of Textiles, the importance of the role of institutional consumers of technical textiles is marked. The mandate provided in government guidelines for its adoption by ministries and particular applications, the investment levels required, and employment generation potential are key to its growth[41]. The rapid nature and rate of change has caused problems of classification, requiring comprehensive expert consultation. Further, the sectoral segments and their distribution have been forecasted using various sources of information including: a primary survey of product manufacturers, raw material suppliers, machinery manufacturers and industry experts. The context provided by the textiles industry creates the scope for the deployment of information and communication technologies in the manufacturing activities of the sector.

4.4 Digital Transformation in the Indian Textiles Industry

The textiles industry has indeed come a long way from the days of the handicraft or artisanal sector to today's high technology powerloom sector. Traditionally, the garment sector, and to a far less extent the textiles sector, has been a labour-intensive industry but with technology advancements there has been a high degree of automation across the entire textile fabrication process from design, fabric creation to finishing. As the industry relies heavily on fine details such as equipment monitoring, stock management for dyes and raw materials, supply chain visibility, workforce management, coordination and analysis, it is most suitable for digital transformation. Quick responses to deviations from standard operating conditions (SOC) are needed to minimise revenue loss and maintain effective use of the workforce. Therefore, its central position in adopting new technologies is noteworthy and so is the amended technology upgradation plan (Patil, 2022).

[41] Technical Textiles Industry in India-Opportunities and Challenges Baseline Study (2020), Report submitted by IIT Delhi to the Ministry of Textiles, Government of India: http://texmin.nic.in/sites/default/files/Baseline Survey Technical Textiles Sector 20042022.pdf

According to the baseline study conducted by IIT Delhi for the Ministry of Textiles in 2020[42], the reported challenges to the adoption of technical textiles include the absence of a formal mechanism for the regular collection of reliable and comprehensive nation-wide data on the production capacity and medium- to long-term production plans of enterprises engaged in this high-value and fast evolving sector of the industry. A low level of adoption of the latest technologies involving 3-D printing and manufacturing has also been identified as a key factor. More importantly, the textiles industry has considerable supply chain challenges such as inventory management, lead time, visibility, collaboration, technology, and logistics. The companies also vary in size and are offering products based on target consumer groups (Giri and Rai, 2013). In addition, there are demands and competitive pressures on the industry. In recent years, the biggest change has been the introduction of artificial intelligence (AI) which is having a major impact on the industry and is going to become more prominent in the future. There are many ways in which AI is being used in the industry, including:

- Automated design, where it is used to create new designs automatically. This is done by either producing designs from scratch or through the modification of existing designs.
- Manufacturing, where it can be used to automate the process of manufacturing including tasks such as fabric cutting, sewing, and printing.
- Quality control through identifying defects in products and meeting customers' specifications.
- Sales and marketing through identifying potential customers and helping in the promotion of products to them[43].

Further, AI has a key role in producing new fabrics as well as improving manufacturing processes deployed in the textiles industry. In terms of the development of new fabrics, it helps produce fabrics with improved quality, unique properties, and texture. The design of improved manufacturing processes results from an analysis of data obtained from manufacturing plants, identifying ways to improve efficiency and reduce wastage. In terms of better textile design, AI can help create patterns and designs that are more intricate and detailed than those produced using conventional design technologies. These technologies can be used to create fabrics that are more responsive to the wearer's environment. AI is also used for colour and pattern selection, 3-D printing of fabrics to create textile fibres and fabrics that are stronger, more durable and have unique properties. The use of AI in the textiles industry is however in its nascent stages, though it is amply clear that it has the potential to revolutionise the way textiles are manufactured. In terms of the cost-cutting initiatives of the textiles industry in India, AI is well-placed to process optimisation and result in considerable savings[44]. A key barrier to the adoption of AI is in relation to the hard and long research requirements on product and service innovations and dilated product or service lead times at the manufacturing end. Technologies such as virtual reality simulations are dealing with these issues. The manufacturing process with its attendant costs is a key barrier to competitiveness. AI can help with fibre grading, yarn quality prediction, fabric issue diagnostics and dye recipe prediction. Adaptive Neuro Fuzzy Inference System (ANFIS) have been used to assess yarn characteristics. Automated neural networks (ANN) are used to anticipate utility attributes including moisture and heat transfer rates in fabrics, as well as air permeability. The use of neural networks in textile colouring and printing has reduced the need for human contact by predicting dye formulas, matching colours and identifying dyeing faults. As fabric quality is determined by the quality of the yarn in most textiles, finding faults in yarn and maintaining fabric quality is crucial. The rate of discovery by humans is less than 30% in such cases where defects are more than 2 metres in length and machines move faster than 30 metres per minute whereas thresholding can detect up to 90% of the defects in the textile. Fabrication has started using image analysis in addition to computers and algorithms. Online monitoring and process management are currently being used by big yarn production units. AI can detect defects, scientifically analyse failure rates, and adjust control settings to maximise spinning. Deep learning and machine learning enhance the system using high resolution cameras and pre-programmed computer systems for error reduction, fabric formation and production. The prospects of adoption of Industry 4.0 still appear mixed, given the overall context of the industry and the scope of modernisation achieved and the existing infrastructure in machinery components. There is greater need for interaction between the software industries to develop custom-made solutions for end-to-end digital textile manufacturing.

[42] Technical textiles are engineered products with definite functionality. They are manufactured using natural as well as man-made fibres such as Nomex, Kevlar, Spandex, Twaron that exhibit enhanced functional properties such as higher tenacity, excellent insulation, improved thermal resistance.

[43] For a full review of such technologies under Industry 4.0 , see V Alcacer and V Cruz-Machado, "Scanning the Industry 4.0: a Literature Review on Technologies for Manufacturing Systems", Engineering Science and Technology, Volume no. 22, pp. 899-919, DOI:10.1016/j.jestch.2019.01.006

[44] Technical Textiles Industry in India-Opportunities and Challenges Baseline Study (2020), Report submitted by IIT Delhi to the Ministry of Textiles, Government of India: http://texmin.nic.in/sites/default/files/Baseline Survey Technical Textiles Sector 20042022.pdf

5. Policy Landscape

Policy Landscape

The Indian textiles industry is one of the earliest established industries in the Indian economy. The diversity of fibres found in India, the wealth of craftsmanship, artistry and intricacy and a broad spectrum of production techniques have attracted buyers from all over the world for centuries. It is also a highly fragmented and labour-intensive industry, with small-sized businesses and an unorganised sector dominating the industrial landscape. Given the complex structure of the sector with its three main divisions; handlooms, powerlooms and a highly mechanised mill industry, the Government of India has been following a protectionist policy for handlooms vis-à-vis powerloom and mill sector for many decades after independence. Policy-induced bias against large textile mills and garment units served to encourage systematic fragmentation of the textiles sector (Ganesh, 2002). Post-independence, policies for the textiles sector were designed to limit textile imports and support domestic textile firms in order to attain self-sufficiency. The government's policies that required licensing of textile mills discouraged the expansion of composite textile mills and encouraged the growth of small independent spinning mills paving the way for a large informal sector that lacked modern technology and environmental control. Furthermore, tax anomalies and antiquated labour regulations also encouraged firms to break down businesses into small units to avail exemptions or to bypass labour unionisation issues. For almost 50 years, the policy regime that encouraged fragmentation has stifled the growth and modernisation of the Indian textile industry (Ganesh, 2002).

After the 1991 economic reforms, the Government of India adopted various policies from time to time to develop the textile and apparel sector. Despite its progress, this sector is still categorised as labour-intensive and unorganised, operating in small scale units that still make use of conventional techniques and methods of production, having lower quality and productivity, with higher use of water, energy and chemicals and associated waste and pollution. The sector requires additional structural reforms and continuous support in terms of trade negotiations and greater investments in technology and infrastructure (CRISIL research, 2021).

The Indian textiles and apparel industry has the potential to stimulate employment and promote the development of related industries (Sun C. et al., 2018). Textile production has backward linkages with agriculture and allied activities, especially - but not exclusively - in the case of natural fibres (Gopalakrishnan, 2017). This calls for better coordination between the Ministry of Textiles and other ministries and departments (like agriculture, finance and commerce and industry) to support the development of a strong and vibrant textiles and apparel industry.

Explained below are the core policies of the textiles and apparel sector in India that are addressed in turn, along with the supporting policies that have a bearing on this sector.

5.1 Core Policies of Indian Textiles Sector

National Textile Policy 2000 (NTP 2000)

In the words of applied economist, G. Badri Narayanan, "the textile policy framework in India has been motivated by five main issues: regulation of inter-sectorial competition, provision of cheap cloth, fibre policy, modernisation of the industry and sickness and rehabilitation of mills...the policy has been aimed at learning from the bad experiences of the British Raj and ushering the industry into a new era. However, major developments in the industry happened only in the late twentieth century".[45] Taking note of the new opportunities and challenges presented by the changing global environment and world trading system in textiles, the Ministry of Textiles, Government of India, unveiled the "National Textile Policy 2000" (NTP 2000) with the vision of developing a strong and vibrant industry that can produce international quality products at a reasonable price to fulfill the growing consumer demand, contribute to sustainable employment and the economic advancement of the country, and also gain confidence to enhance global market share. The NTP 2000 aims to sustain and strengthen the traditional knowledge, skills and capabilities of weavers. Simultaneously, its goal is to enable the industry to build world-class state-of-the-art manufacturing capabilities in conformity with environmental standards by encouraging both foreign direct investment as well as research and development in the sector. It seeks active cooperation and partnership of the state governments, financial institutions, entrepreneurs, farmers and NGOs in the fulfilment of these objectives.

[45] Narayanan, G. Badri, Implications of History for the Current Policies and Industrial Structure: The Case of the Indian Textile Sector (November 20, 2013): https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2358020

Though the policy was introduced to energise the textiles sector in five years, it fell far short of its targets. It has been termed as being discriminative in nature and its principles are applied selectively (CUTS International, 2006). Table 5 and Table 6 list the shortcomings of NTP 2000 along with recommendations that can be incorporated.

TABLE 5: Shortcomings of NTP 2000

Shortcomings
• Fails to integrate itself into overall growth and development policies. • Ignores the domestic markets and how the Indian textile sector can effectively respond to domestic demand pressures, competition from cheap imports and competition from its own sub-sectors. • Estimates investment required for the growth in exports but there are no corresponding estimates provided for how much fibre, machinery or human resources are required to achieve the same. • Aspects of trade facilitation and streamlining of transport and custom clearances have not been integrated • Fails to address issues of handloom sector, small-scale firms, non- corporate entities and unorganized sector • Ignores labour market implications of the policy and its effect on access to employment. • Discriminative in nature • Principles applied selectively

Source: CUTS International, 2006

TABLE 6: Recommendations for policy improvements

Recommendations
• Spread awareness of and conduct assessment of implications of world trade organization (WTO) related agreements on textile and clothing industry in India • Identify and deal with the discriminatory policies of countries (in form of bilateral or regional trade agreements and WTO provisos such as environmental and labour standards etc.) that can impact textile exports of India • Comprehensive analysis of the environmental impact of textile manufacturing activity to be done along with an assessment of solutions adopted by the industry to deal with the problem. • Adopt fibre neutral policy to benefit the entire value chain. • Address modernization, mechanization, credit and investment needs of the industry • Address the skill gaps • Address environmental concerns of the textile industry for 21st-century trade operations • Textile industry to be kept in priority/lowest slab of GST as it provides a basic necessity to masses with large scale employment potential • Eliminate long-standing discrimination between cotton and man-made fibre on excise duty front (fibre neutrality) • Processing remains the weakest link in the Indian textile value chain. For processing separate pollution-free zones to be set up to increase consumption across the entire value chain from fibre to garments • Encourage and support industry-academia linkage by creating national knowledge functional hubs that would increase the interface between industry and academia and would also provide an institutional mechanism for faculty development

Source: CUTS International, Briefing paper, 2006, Ministry of Textiles Annual Report 2013-14 and FICCI's Suggestions for National Textile Policy 2013

In 2013, after 13 years of policy formulation, the Government of India constituted an expert committee to review all the aspects of the NTP 2000 and formulate a "New National Textile Policy" under Shri Ajay Shankar, Chairman, of the then National Manufacturing Competitiveness Council (NMCC). The committee noted that the textile industry had undergone various changes in domestic as well as international markets in terms of modernisation and technological advancement. The committee also highlighted that trends in the global textile industry offer an enormous opportunity to the Indian industry to enhance its share in world trade, provided a supportive policy framework is put in place to make it more competitive and self-reliant in our open market economy (Annual Report, 2013-14). The draft "Vision, Strategy and Action Plan" was submitted by the Chairman after a detailed process of stakeholder consultations across the entire value chain for attaining the targets set out in the vision for exports, investment and employment by FY 2024-25. At present, the New National Textile Policy has not yet been finalised and it is still at the draft stage.

National Jute Policy 2005 - 2010

Jute contributed significantly in foreign exchange earnings for the countries producing it during the 1960's and 70's (Ammayappan et.al., 2015). However, during the 1980's jute started losing its prime position in the market as it was substituted by bulk handling techniques and the use of synthetic material. Recognising the importance of jute for the economy, the Government of India announced the "National Jute Policy 2005" with the intent to: revitalise the jute economy by adopting supportive measures; produce

good quality fibre products to meet the growing demand of the country and international buyers; ensure remunerative prices to the jute farmers; contribute to the provision of sustainable employment and growth of the economy and compete with confidence for enhancing global market share. Further, the policy was also directed towards making information technology (IT) a vital part of the entire value chain of jute production so that the industry can achieve international standards in terms of quality design and marketing. The policy aimed to ensure the active participation and partnership of state governments, financial institutions, entrepreneurs, and farmers' organizations in the fulfilment of these objectives (Ministry of Textiles, 2005). It did, however, face challenges on the implementation side. The advantages of jute being eco-friendly were not fully capitalised on and diversified products from decentralised units were not marketed efficiently. Moreover, the industrial and farm sectors were not modernised enough to cash in on the benefits of jute.[46] To promote its usage, the Government of India has expanded the scope of mandatory packaging norms under the "Jute Packaging Material (JPM) Act", 1987. In October 2020, the Cabinet Committee on Economic Affairs, chaired by Prime Minister Shri. Narendra Modi, approved that 100% of the food grains and 20% of the sugar shall be mandatorily packed in diversified jute bags (PIB, 2020). Though India is one of the few and one of the largest producers of jute in the world, the development and integration of jute as a mainstream fibre in the Indian textile industry has not been possible, mainly due to a lack of adequate R&D for jute product development, diversification, and investment. The sector also requires government support in the scaling-up and ommercialization of developed technologies to bring innovative products or processes to the market.

National Fibre Policy 2010-20

India's palpable aspiration to assume its rightful place on the world fibre map requires some big changes. The industry needs a policy that benefits all, right from raw materials such as cotton, cotton yarn and man-made fibres to garments, the spinning sector, exporters and domestic markets. Taking note of this, the Ministry of Textiles designed the "National Fibre Policy 2010-20" to strengthen the fibre economy of the country and to make the textile and clothing sector competitive in the long run. The policy endeavors to ensure the balanced growth of the entire sector by promoting all the fibres equally and equitably. It aims to enhance the growth of the fibre sector by providing technological upgradation and institutional support, income and employment generation capacity along with improving the textile industry's competitiveness and brand image in the world market for its products (GoI, 2010). Furthermore, the policy also addressed the problem of infrastructure bottlenecks and aimed to aid with building capacity in both industry segments and the human capital required to build a strong and globally competitive textile industry. To implement the fiscal and non-fiscal measures envisaged in the National Fibre Policy, a budget allocation of INR 32,000 crore was planned under the "Technology Upgradation Fund Scheme". Fiscal measures mainly include the rationalisation of the duty structure (customs duty exemption, export incentives, neutral excise policy); while non-fiscal measures focus on improving the quality and quantity of fibres (market development support, capital subsidy, sustained R&D, etc.). However, major constraints for the fibre industry that need to be addressed include the lack of global competitiveness, limited number of players, levy of anti-dumping duties and differential treatment in tax rates (FICCI, 2015).

National Silk Policy 2020

India is the second largest producer in the world after China and largest consumer of silk in the world with all the commercially exploited silks. The silk production process involves a series of on-farm and off-farm activities with enormous employment potential, particularly involving rural women. The government needs to re-assess the status, potential and constraints of the silk sector in the wake of socio-economic changes including the transition from an agriculture-based to a service-based economy (Bhattacharjya et al., 2020). Realising this need and opportunity, the Central Silk Board (CSB), a statutory body constituted in 1948 for the development of the sericulture and silk industry in the country, formulated the "National Silk Policy 2020" with a vision to create a globally competitive and resilient silk sector meeting the needs of the present and future generations.

Silk Samagra 2 (2021-2026)

In addition, the Government of India, through the CSB, has implemented the central sector scheme "Silk Samagra 2" (2021-2026), an "Integrated Scheme for Development of Silk Industry" (ISDSI), which was approved by the Cabinet Committee on Economic Affairs on 19th January 2022. The scheme comprises four core components viz. (i) R&D, training, transfer of technology and I.T. initiatives, (ii) seed organizations, (iii) coordination and market development and (iv) Quality Certification Systems (QCS) / Export brand promotion and technology upgradation. The scheme also

[46] Sourced from: https://economictimes.indiatimes.com/industry/cons-products/garments-/-textiles/jute-industry-fails-to-cash-in-on-changing-global-trends/articleshow/2118543.cms

comprises sub-components focusing on beneficiary-oriented critical field level interventions that shall be implemented by state governments with the CSB (CSB, 2020) funding. The silk sector stands for livelihood opportunities for millions of people, and the development of this sector will be dependent on the meticulous implementation and effective monitoring of all such policy measures.

National Handloom Development Programme (2021 - 2026)

The handloom sector is considered to be one of the largest unorganised sectors and it constitutes an integral part of rural and semi-rural livelihoods, engaging over 3.5 million people. The sector is also said to be encouraging women empowerment as it engages over 2.5 million female weavers and allied workers. To facilitate the growth and development of handloom weavers, the "National Handloom Development Programme" (NHDP) was formulated for its implementation during FY 2021-22 to FY 2025-26. It follows a needs-based approach for the integrated and holistic development of handlooms and the welfare of handloom weavers. It will support weavers, both within and outside the cooperative fold, (including self-help groups) towards raw material, design inputs, technology upgradation, concessional credit, marketing support through exhibitions, and in creating permanent infrastructure in the form of Urban Haats, Mega Handloom Clusters, etc. (Ministry of Textile, 2021).

Yarn Supply Scheme (YSS)

Handloom weaving is a labour-intensive industry that is spread across the country, mostly in rural areas. The yarn is the main raw material used by the sector. Trade of yarn was controlled by a few traders and due to the dependency on them, the availability of yarn was falling short thus leading to the escalation of its prices. With an objective to curb this problem, the Government of India introduced the "Yarn Supply Scheme" (YSS) in 1992 to make all types of yarn available at the mill gate price. Implemented through the National Handloom Development Corporation (NHDC), the scheme also seeks to set a benchmark price and quality of yarn in the open market. Under the scheme, transportation expenses involved in the supply of yarn are reimbursed by the government and later, a price subsidy on silk and cotton hank yarn was introduced in January 2012 (NHDP, 2021).

The YSS has been renamed as the "Raw Material Supply Scheme" (RMSS) and has been approved for implementation during the period from FY 2021-22 to FY 2025-26. The objective of the scheme is to ensure that consistent supply and quality parameters are maintained in the market, and to facilitate handloom weavers' engagement in the sector to help compete with the mill sector. While the government tries to establish the environment for harmonious growth of the entire textile industry, it also ensures that there are well defined and delineated areas for handlooms that wouldn't be taken undue advantage of by powerlooms and mills. The Ministry of Textiles has been managing the "Implementation of the Handlooms (Reservation of Articles for Production) Act, 1985" to ensure the effective implementation of its provisions and the scope of the scheme has now been expanded to promote the sale of genuine handloom products (Ministry of Textiles, 2021).

Comprehensive Handicrafts Cluster Development Scheme (2021 - 2026)

To scale-up the infrastructural and production chain at handicrafts clusters that are mostly unorganised and have not kept pace with modernisation and technological upgradation, the "Comprehensive Handicrafts Cluster Development Scheme" (2021 - 2026) was announced by the government.[47] The growth of the handicraft sector, like any other sector, depends upon the improvement in infrastructure, adaptation of modern techniques, machinery, process, product development and the diversification and creation of high-end brands. Innovative designs as well as technical know-how, furthered by brand building of traditional products hold the key to creating a niche market for the products manufactured by the clusters. Therefore, the proposed programme is expected to support the upgradation/creation of infrastructural facilities coupled with market linkages and product development and diversification (Ministry of Textiles, 2021). The Ministry of Textiles has approved continuation of the Comprehensive Handicrafts Cluster Development Scheme (CHCDS) with a total outlay of INR 160 crore. The scheme will continue up to March 2026. Infrastructural support, market access, design and technology upgradation support, etc., will be provided to handicraft artisans under this scheme[48].

Wool Development Scheme

The Ministry of Textiles approved the "Pashmina Wool Development Scheme" under the "Integrated Wool Development Programme" (IWDP) with a budget allocation of INR 29.25 crore for implementation from FY 2021-22 to FY 2025-26. Under the scheme, financial assistance will be

[47] Sourced from: https://www.texmin.nic.in/sites/default/files/11d Guidelines of development of mega cluster scheme Handicrafts nmcc cs 20090312.pdf
[48] Sourced from: https://pib.gov.in/PressReleasePage.aspx?PRID=1761118

provided in the form of a revolving fund for the procurement/marketing of pashmina wool in UT of Ladakh and UT of J&K. A project to set up a dehairing plant along with ancillary machines at Leh, UT of Ladakh, with a project cost of INR 19.75 crore has been sanctioned and INR 12.92 crore have already been released (PIB Release ID: 1847885, 2022).

Schemes for Technical Textiles

With new developments in material science and technology, one segment of the textile industry that is steadily gaining momentum is the segment of technical textiles. India's manufacturing capability in technical textiles came to the fore during the COVID 19 pandemic. By definition, technical textiles are functional products with end-use applications across multiple non-conventional textile industries such as healthcare, construction, automobile, aeronautical, sportswear and protective gear, among others. India is the 5th largest producer of technical textiles in the world with a market share of 8%.[49] The domestic market for technical textiles has increased from US$ 10 billion in FY 2012-13 to US$ 20.5 billion in FY 2021-22, with exports more than doubling to US$ 2.2 billion during the same time period (NTTM Newsletter, June 2022). Technical textiles products demonstrate enhanced performance over traditional textiles. The sector holds opportunities across various flagship missions and schemes of the Government of India including the: Jal Jivan Mission, Mission for Integrated Development of Horticulture, National Health Mission, National Investment Pipeline, as well as strategic sectors such as defense, space and paramilitary. The development of technical textiles also provides impetus to the "Atmanirbhar Bharat" and "Make in India" initiative by focusing on import substitution (NTTM Newsletter, June 2022). The demand for technical textiles is derived from the development and industrialisation of the economy.

Despite showing impressive growth over the years, per capita consumption of technical textiles in India remains relatively low (1.7 kgs) in comparison to other developing countries (10-12 kgs) [KPMG, 2019). Technical textiles provide new opportunities for the Indian textile industry to experience growth and to have a long-term sustainable future. To boost this sector, the Ministry of Textiles launched the "Scheme for Growth and Development of Technical Textiles" (SGDTT 2007 - 2011) in 2007-08 with the fund outlay of INR 46.60 crore. The scheme was comprised of three main components; (i) a baseline survey to create an accurate database of statistics and information related to the technical textile industry that will facilitate effective policy decisions by the government and business decisions by industry stakeholders; (ii) awareness campaigns- more than 60 awareness programmes/seminars/ workshops were organised across the country; (iii) creation of Centres of Excellence (CoE)- four CoEs have been set up for four thrust segments within the technical textiles industry (see Table 7[50]).

TABLE 7: Centres of Excellence established under SGDTT

Centre of Excellence	Location	Focus segment
Bombay Textile Research Association (BTRA)	Mumbai	Geotech
The Synthetic & Art Silk Mills' Research Association (SASMIRA)	Mumbai	Agrotech
The South India Textile Research Association (SITRA)	Coimbatore	Meditech
North India Textile Research Association (NITRA)	Ghaziabad	Protech

These CoEs provide infrastructure support to the industry with regards to testing, training, information, etc., at a single location for the convenience of the manufacturer of technical textiles and other relevant stakeholders. The scheme completed its tenure in FY 2010-11.

In 2010-11, the Ministry of Textiles launched the "Technology Mission on Technical Textiles" (TMTT) with two mini-missions for a period of five years with a fund outlay of INR 200 crore during December 2010. The first mini-mission of this scheme was to establish four more CoEs other than those built under the SGDTT Scheme (see Table 851). This was done with an objective of standardisation, creating common testing facilities with national / international accreditation, indigenous development of prototypes and maintaining a resource centre with IT infrastructure.

[49] Sourced from: https://pib.gov.in/PressReleasePage.aspx?PRID=1805372
[50] Sourced from: http://texmin.nic.in/sites/default/files/scheme_technical_textile_070116.pdf
[51] Ibid.

TABLE 8: Centres of Excellence established under TMTT

Centre of Excellence	Location	Focus segment
DKTE'S Textile & Engineering Institute	Ichalkaranji	Nonwoven
PSG College of Technology	Coimbatore	Indutech
Ahmedabad Textile Industries Research Association (ATIRA)	Ahmedabad	Composites
Wool Research Association (WRA)	Thane	Sportech

The second mini-mission was to upgrade the four CoEs under the SGDTT, to provide support for the development of domestic and export markets for technical textiles. The TMTT scheme was extended for another two years, from FY 2015-16 to FY 2016-17.

In order to help the potential investors to enter into technical textiles, the Ministry of Textiles has set up **Focus Incubation Centres (FIC)** in the COEs established under the TMTT scheme on a plug and play model. FICs are advanced infrastructure facilities supported by the Ministry of Textiles to promote innovations and new generation product development for the technical textiles sector. They not only inspire startups but also facilitate strong industry-institute partnerships.

Agrotextiles (textiles used in the field of agriculture) and geotextiles (textiles used in construction) are growing areas of technical textiles. In December 2012, the Ministry of Textiles launched the "**Scheme for Promoting Usage of Agrotextiles in NER (Northeast Region)**" for a period of five years (FY 2014-15 to FY 2018-19) with a total fund outlay of INR 55 crore. The objective of the scheme was to promote awareness about agrotextiles and increase their usage in agriculture, horticulture/ floriculture, sericulture and allied activities in the NER. Another "**Scheme for Promoting Usage of Geotextiles in NER**" was approved on 3rd December 2014, with a total outlay of INR 427 crore for a period of 5 years from FY 2014-15 to FY 2018-19. These schemes focused on demonstrating the effectiveness of technical textiles in maximising the agriculture output of the region. Due to the overwhelming response to the schemes for promoting the usage of agrotextiles in NER, a new "**Scheme for Promoting Usage of Agrotextiles in Rest of India**" was also introduced and funded under the "Mini-Mission-II of Technology Mission on Technical Textiles" (TMTT) for a period of two years (FY 2015-16 & FY 2016-17) for promoting the usage of agrotextiles across the country (Ministry of Textiles, 2016).

To further boost the export of technical textiles, the Government of India brought 33 technical textile products under the ambit of the **"Focus Product Scheme" (FPS)**. FPS was launched in 2006 to incentivise the export of products that have high export intensity or employment potential to offset infrastructure inefficiencies and other associated costs involved in the marketing of these products (Ministry of Textiles). The government has also announced its intention to launch a "Focus Product Incentive Scheme" with special emphasis on the man-made fibres and technical textiles segments.

Production Linked Incentive (PLI) Scheme for the Textiles Sector

In September 2021, the Government of India approved the "**Production Linked Incentive (PLI) Scheme**" for textiles with a budgetary outlay of INR 10,683 crore focusing on man-made fibre (MMF) apparel, MMF fabrics, and products of technical textiles to enhance India's manufacturing capabilities and exports. The scheme aims to help India become a global champion and a sourcing hub for MMFs as it has historically been for cotton garments. It aims to attract investment (both domestic and foreign) and seeks to help realign the export strategy which has always been dependent on cotton products.[52] Reduction of import duty on cotton to zero will also give a boost to the sector. According to the Government of India's 14th of April 2022 press release, a total of 61 applicants were selected under the PLI for textiles scheme, which translates to a total investment of INR 19,077 crore and a projected turnover of INR 184,917 crore over a period of 5 years with the proposed direct employment of 240,134. Finally, it is worthwhile to note that the scheme accords priority to investments in Tier 3 towns, Tier 4 towns and underdeveloped areas of the country. It also focuses on empowering women and increasing their participation in the formal economy. In December 2022, the government announced that the PLI Scheme attracted investment of INR

[52] Sourced from: https://www.business-standard.com/article/economy-policy/union-cabinet-approves-rs-10-683-crore-pli-scheme-for-textile-sector-121090801448_1.html

1526 crore as approval letters were issued to 56 applicants who met the eligibility criteria.[53]

Draft Production Linked Incentive Scheme (PLI 2.0) for Apparel and Home Textiles

In October 2022, the Ministry of Textiles released a draft PLI 2.0 which is likely to offer incentives for the manufacturing of garments and home textiles. The new "PLI Scheme for Apparel and Home Textiles" is likely to relax the selection criteria and will attract investment and reduce import dependence on the textile accessories sector.[54]

PM Mega Integrated Textile Regions and Apparel (PM MITRA) Parks

In addition to the PLI Scheme, the Government of India has proposed a scheme of "**Mega Integrated Textile Regions and Apparel Parks**" (MITRA) to create world-class infrastructure with plug and play facilities with a budgetary outlay of INR 4,445 crore for a period FY 2021-22 to FY 2027-28. The aim is to develop integrated large scale and modern industrial infrastructure facilities for the entire value chain of the textile industry. In October 2021, the government issued a notification for setting-up of 7 PM MITRA parks in partnership with willing state governments. [55] These parks are planned to be developed primarily in public-private partnership mode. Several states such as Tamil Nadu, Punjab, Odisha, Andhra Pradesh, Gujarat, Rajasthan, Assam, Karnataka, Madhya Pradesh and Telangana have expressed interest in the scheme. The scheme seeks to generate about 100,000 direct and 200,000 indirect employment per park. It is envisaged to help India in achieving the United Nations Sustainable Development Goal 9 ("Build resilient infrastructure, promote sustainable industrialization and foster innovation").

Scheme for Incubation in Apparel Manufacturing (SIAM)

The "**Scheme for Incubation in Apparel Manufacturing**" (SIAM), which was launched on a pilot basis in January 2014, is a demand-driven scheme that is being implemented by the Ministry of Textiles. It seeks to promote entrepreneurs in apparel manufacturing by providing them with an integrated workspace and linkages-based entrepreneurial ecosystem with plug and play facilities which helps them in reducing operational and financial costs for establishing and growing a new business. As per the July 2019 official press release, three projects have been sanctioned by the government in Madhya Pradesh, Odisha and Haryana.[56] With these measures in place, the government hopes to help the textile and apparel industry, MSMEs and exports (PIB, 2021).

National Technical Textiles Mission (NTTM 2020-24)

While the PLI Scheme aims to attract investments in the technical textiles segment, the "**National Technical Textiles Mission**" (NTTM) aims to promote R&D in the segment. The NTTM was launched in March 2020 with the intention to position India as a global leader in technical textiles. It was created with the approval of the Cabinet Committee on Economic Affairs (CCEA) with an INR 1480 crore outlay and a four-year implementation period from FY 2020-21 to FY 2023-24. The mission consists of 4 components (GoI, 2020):

- Research, innovation and development - It includes R&D of specialty fibres from carbon, nylon-66, glass, aramid and other high-tech polymers; increased application of geotextiles, agrotextiles, medical textiles, protective textiles and other segments of technical textiles in various application areas. Both basic research activities and application-based research will be conducted by scientific/industrial/academic laboratories of repute, as approved by the Mission Steering Group.
- Promotion and market development - An annual growth rate of around 15-20% will be targeted to raise the level of the domestic market to US$ 40-50 billion by the year 2024. It includes promoting awareness amongst users, bringing in large-scale investments, and encouraging high-end technical textiles products.
- Export promotion - Aims to promote the exportation of technical textiles, ensuring a 10% average growth in exports per year up to FY 2023-24 (Ministry of Textiles, 2020). Also, a separate Export Promotion Council for technical textiles is proposed for effective coordination and promotion activities in the segment.
- Education, training and skill development - Aims to promote technical education at higher engineering and technology levels in technical textiles and its application areas covering the engineering, medical, agriculture, aquaculture and dairy segments. Promoting skill development and creating a pool of highly skilled manpower resources.

The NTTM seeks to support the development of indigenous machineries and process equipment for technical textiles.

[53] Sourced from: https://www.livemint.com/news/india/pli-scheme-for-textiles-attracts-rs-1-536-cr-in-investments-govt-11672053569744.html
[54] Sourced from: https://www.financialexpress.com/economy/govt-may-relax-key-criteria-to-sweeten-textile-pli-2-0/2690440/
[55] Sourced from: https://pib.gov.in/PressReleasePage.aspx?PRID=1765737
[56] Sourced from: https://pib.gov.in/Pressreleaseshare.aspx?PRID=1579533#:~:text=The%20objective%20of%20the%20Scheme,and%20growing%20a%20new%20business

The promotion of innovation amongst young engineering/ technology/ science standards and graduates along with the creation of innovation and incubation centres promoting startups and ventures is one of the key objectives. Furthermore, the NTTM aims to build an adequate pool of highly skilled manpower resources for meeting the needs of relatively sophisticated technical textiles manufacturing units. It also seeks to promote the development of biodegradable technical textiles materials, particularly for agrotextiles, geotextiles and medical textiles.

In October 2021, pilot projects for geotextiles skilling were launched under the NTTM with the objective of skilling technical personnel associated with the application of geosynthetics in infrastructure projects. The Ministry of Textiles coordinated with other concerned government departments/state governments for mobilising the trainees. Special skill development courses were conducted concurrently by the Indian Institute of Sciences Bangalore, Indian Institute of Technology (IIT) Madras and IIT Roorkee (NTTM newsletter, June 2022).

The selection criteria for NTTM projects is stringent. Currently, 20 strategic research projects worth INR 30 crore in the areas of specialty fibres and geotextiles have been approved under the mission (NTTM newsletter, June 2022).

Technology Upgradation Fund Schemes

Such schemes were launched in order to provide the Indian textile Industry with the same technological edge as in developed countries, especially in the weaving and processing segments. In April 1999, the GoI launched the "**Technological Upgradation Fund Scheme**" (TUFS) 1999-2007 for the textile and jute industries to facilitate modernisation and technology upgradation for the period of 5 years, which was later extended to March 31st, 2007. It was a flagship scheme of the Ministry of Textiles, and all technical textiles machinery was covered. To further enhance feasibility and inclusiveness in the domestic market as well as international market, it was suggested to make funds available to the existing domestic textile industry and to set up new units with state-of-the-art technology (CAG report, 2016). To fill the gap, the "**Restructured TUF Scheme**" (RTUFS) 2011-2012 was introduced. The scheme was reviewed by the Expenditure Finance Committee in March 2013, and it was suggested to continue the scheme in the 12th five-year plan. Thus, the scheme was revised and restructured as the "**Revised Restructured Technology Upgradation Fund Scheme**" (RR-TUFS) with effect from April 1st, 2013 to March 31st, 2017.

In line with initiatives such as "Make in India" and "Zero Defect and Zero Effect", the Ministry of Textiles launched the "**Amended Technology Upgradation Fund Scheme**" (ATUFS 2016-22) in January 2016 for a period of six years. The objective of the scheme was to provide a one-time capital subsidy for investments in the employment and technology intensive segments of the textile value chain, keeping in view the promotion of exports and imports substitution. But the ATUFS did not include the spinning sector, so the Ministry of Textiles drafted a new scheme to replace ATUFS by including an element of incentivising the machinery manufacturers too. Though these TUFS have supported modernisation and expansion in the textile and clothing industry, delay in disbursement of TUFS has been a major deterrent and an area of improvement for policymakers.

Technology upgradation is important, but it must be complemented with upgradation of infrastructure and ease of doing business. In this regard, the "**Scheme for Integrated Textile Parks**" (SITP) was approved in the 10th five-year plan in 2005 to provide the industry with world-class infrastructure facilities for setting-up their textile units by merging the former "**Apparel Parks for Exports Scheme**" (APES) and "**Textile Centre Infrastructure Development Scheme**" (TCIDS). The scheme also aimed at increasing investments, enhancing employment opportunities, and boosting exports. The GoI approved the continuation of the SITP with modifications for the period of three years from 2017-2020. As of 29th November 2019, a total of 59 parks were sanctioned, out of which 22 were completed while the remaining 37 were under various stages of construction (PIB, 2019).[57]

At present, industries across the globe are going through a paradigm or technological shift termed as Industry 4.0. Big data analytics, artificial intelligence, robotics, automation, and the Internet of Things (IOT) are revolutionising the manufacturing processes by optimising their performance, quality, controllability, and transparency (Nguyen et al., 2019). The key feature of Industry 4.0 is digitisation of the manufacturing sector, which introduces a concept of "smart factories" that examines physical systems, processes and makes decentralised decisions. Textile 4.0 is an interpretation and application of Industry 4.0 in the textiles technology and textiles manufacturing across the supply chain for example, spinning, weaving, finishing and garmenting (textile value chain). Adoption of Industry 4.0 technologies in textile manufacturing represents a great opportunity for the sector to improve its productivity and competitiveness. It would also lead to efficiency and productivity enhancement, reduced time gaps, decreased

[57] Sourced from: https://pib.gov.in/PressReleasePage.aspx?PRID=1594200

costs of production, better quality products and providing finest delivery services to customers, thereby impacting the global landscape. Globally, the textile industry is growing in terms of technological advancement and upgradation. Robotics and automation are advancing faster in clothing manufacturing. Sewbots (sewing robots) are common in garment factories in China. Artificial intelligence is being used by textile companies for trend forecasting and machine diagnostics. Celebrities are flaunting 3-D printed outfits. The market for smart textiles and wearable technologies is set for rapid growth, however, the major concern is whether the Indian textiles sector is ready to adapt to this technological shift. The shift from manual labour to a smart factory is a complex and time-consuming process. It requires a deep insight into advanced technologies that are integral to this process. An information technology gap exists in the Indian textile and apparel industry as does a lack of integration in a supply value chain. Many domestic manufacturing firms are unable to keep up with the rapid changes in the fashion world and the intense global competition due to the lack of a flexible and digital operational structure.

There is a need to bridge the gap in this sector by implementing IT in their respective organizations and connecting the supply chain from end-to-end. To obtain a competitive edge, firms need to invest in Industry 4.0 and the government needs to enable this shift from traditional to smart factories.

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. 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, 2016). 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.

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).

5.2 Initiatives for the Future Workforce

The Indian textile industry is known for its rich and diverse spectrum of activities and for its contribution towards employment generation and inclusiveness. It directly employs over 45 million people in the country, including 3.5 million handloom workers, making it the second largest sector after agriculture that provides employment for both skilled and unskilled labourers. Despite this, there is a rampant shortage of skilled labourers in all segments of the textile value chain as industry is facing an immense challenge in mobilising skilled workers to fulfill the production and technology requirements (Assocham, 2011). Skill readiness of labour for Industry 4.0 also needs to be ensured. The National Skill Development Corporation's "**Skill Gap Analysis Report for Textile and Clothing Industry 2022**" identifies the gaps in the policy and regulatory environment and states that the "textiles and clothing industry comes under the purview of the Contract Labour Act, 1970 which prohibits contract labour for the work that is perennial in nature. In addition, The Factories Act, 1948 poses restrictions on the maximum working hours which restricts the ability of units to meet peak season demand. Moreover, units employing over 100 people currently fall under the purview of the Industrial Disputes Act, 1947 (IDA, 1947). This creates unfair discrimination amongst large companies and the smaller ones and thus, is partly responsible for the lack of economies of scale and poor competitiveness of the Indian textile and clothing industry. The report further points out that "the textile industry (except the spinning sector) is fragmented in nature on account of policy restrictions relating to labour laws and the fiscal advantages enjoyed by the small-scale units…More flexible labour regulations will positively affect the industry. Change in the current regulations can lead to opening up of more employment opportunities. Also, the current regulations prohibit women from being employed in night shifts. Relaxation of the same with adequate

safeguards can lead to more participation of women and help in addressing the skill shortage in the industry."

According to another skill gap study in the "**Apparel Made-ups and Home Furnishing Sector 2021**", just 6.4% of the workforce has received formal training in the apparel sector, 35.8% of the workforce has received informal training in the apparel sector and about 57.8% of the workforce have not received any sort of training. To bridge the skill gap in the industry, the GoI implemented the "**Scheme for Capacity Building in Textile Sector**" also known as "**SAMARTH**" during FY 2017-18 to FY 2019-20. The target of the scheme was to train 1 million people (900,000 in the organised and 100,000 in the traditional sector) over the period of 3 years (2017-2020). As on 25th August 2021, 1565, artisans had benefited by training in 63 SAMARTH Training Centres. Later, the February 2022 press release by the Ministry of Textiles stated that the Ministry has partnered with 13 state government agencies, 92 textile industry, 10 industry associations/ councils and 4 sectoral organizations for training under the SAMARTH scheme. The press release also stated that the scheme has been extended for a period up to 2023-24.[58]

In order to address the problems of skill development in the handicraft sector, the government conceived the "**Human Resource Development Scheme**" during the 11th five-year plan, which was later restructured as "**Skill Development in Handicraft Sector**" in 2021. The scheme comprises 4 components: - 1) Design and technology development workshops focused on fulfilling the design needs of the market and on the development of new designs/prototypes using the existing skills of artisans; 2) The "**Guru Shishya Hastshilp Prashikshan Programme**" for the transfer of traditional craft knowledge from the master craftsperson (Guru) to the new generation artisan (Shishya); 3) The "**Comprehensive Skill Upgradation Programme**" geared towards providing a demand-driven and self-employment oriented training based on the National Skills Qualifications Framework (NSQF); and 4) The "**Improved Toolkit Distribution Programme**" to promote the scalability, uniformity of quality and productivity enhancement of artisans (Office of Development Commissioner (Handicrafts), 2021).

With a view to providing support to the knitting and knitwear sector, the extensive "Scheme for Development of Knitting and Knitwear Sector" under PowerTex India was approved with effect from July 7th, 2019, to March 31st 2020, by the Ministry of Textiles. Though knitting and knitwear was covered under the Amended Technology Upgradation Fund Scheme (ATUFS) for the installation of new machines and advanced technology, there was no scheme for the development of infrastructure, price fluctuations, or access to credit facilities and so this scheme was introduced to bridge the gap.

In 2013, the National Skill Development Corporation (NSDC) approved the **Textile Sector Skill Council (TSSC)**, set up by the Ministry of Finance, Government of India, for the development of skills in the spinning, weaving, processing and handloom sectors of the textile industry. The TSSC is an organization represented by industry, government and academia to develop innovative skill solutions and to invest in skills and job creation. It seeks to define skill requirements of the industry and to create a deployable talent pool of workforce for the textile industry. TSSC is incubated by textile industry associations and training providers including textile research associations and the Development Commissioner of Handlooms office. The TSSC can play a vital role in the skills development of the sector by ensuring that the quality of training meets prevailing industry needs for current and upcoming technologies. It can also ensure that the quality of training provided by the training providers (textile mills) is of a high standard, and periodically review the demand and supply of skilled personnel, identify shortfalls in numbers and skill sets as well as trends and future requirements and benchmark international practices. Most importantly, such skill councils have the ability to bring employers, training providers, academia and policymakers on the same platform and create a system to catalyse the unorganised sector to be an organised one, creating more employment opportunities (Skill India, 2022).

The Indian textiles and apparel industry has tremendous potential but only a portion of it has been exploited due to government policies marked by ad hocism, fragmented and myopic vision, and political opportunism (Verma, 2002). The textile industry has historically been a highly regulated industry subject to numerous controls and regulations (GoI Expert Committee on Textile Policy, 1999). Over the years, significant investments have been made by the government through various schemes to foster productivity and global competitiveness. Many government control orders and notifications that are still in force even after years of liberalisation and deregulation have a bearing on the competitiveness and exports in a sector that needs urgent transformation. It is equally important to note that emerging technologies and rapid automation accompanied by the rising demand for skilled workers have put a premium on training which in turn is associated ironically with a tight labour market, better working conditions and higher than minimum wages for a subset of the workers in this labour-intensive sector. There is a need to calibrate skill

[58] Sourced from: https://static.pib.gov.in/WriteReadData/specificdocs/documents/2022/mar/doc202231424801.pdf

requirements in alignment with Industry 4.0 technologies that are drastically changing the nature of work.

Studies have shown that globalisation has necessitated the cost-competitiveness of manufacturing processes, which can only be achieved through economies of scale. The Indian textiles and apparel sector has failed to achieve economies of scale due to the fragmented structure of its value chain, which is primarily a legacy of government policies that have favoured labour-intensive, small-scale firms as opposed to large-scale firms (CII-EY joint study, 2007). This fractured condition of the textiles sector is also reflected in a large number of export promotion councils and industry associations where each industry body looks after its respective interests, which is a major hurdle in making the industry competitive.

In conclusion, the GoI has enlisted a plethora of schemes and regulations for the textiles and apparel sector that need to be reviewed in view of their limited usefulness. Policy improvements like the removal of policy bias against synthetic fibre/yarn and the rationalisation of duty structure across the entire value chain from fibre to retailing can go a long way in realigning the skewed structure of the industry, which can hence promote fair competition, attract more investments and raise the technology and quality standards. In a world that is increasingly driven by the 2030 Agenda for Sustainable Development and Climate Action, governments and businesses must also critically re-evaluate their approaches and priorities to reflect their commitment to improving the environmental performance of the sector while expanding its activities in the coming years.

6. Results and Analysis

Results and Analysis

This chapter sets out to analyse the results of the "Indian Textile and Apparel SSI Survey" (ITASSI 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 food and beverages 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 ITASSI.

6.1 Descriptives

The composition of the actors in the ITASSI Survey has been detailed in the Survey Methodology section. Table 9 below shows the actor distribution and response rate.

TABLE 9: Indian Textiles and Apparel SSI - 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	
2085	**1198**	**57.46%**	**6**	**25**	**63**	**27**	**200**	**121**	**60.50%**	**1319**

The overall response rate of the survey is 58%. As shown in the Table 9 above, the response rate of the industry is 57% while the response rate of non-firm actors is 61 % out of which intermediaries account for 52% of data collected in the non-firm category, followed by arbitrageurs and KBIs. There were only 6 responses from the government, which constitutes 5% of the data collected in the non-firm category.

Figure 7 below summarises the distribution of respondents by actor group with the majority belonging to industry (91%), followed by intermediaries (5%), arbitrageurs and KBIs (2% each).

FIGURE 7: Actor distribution of respondents

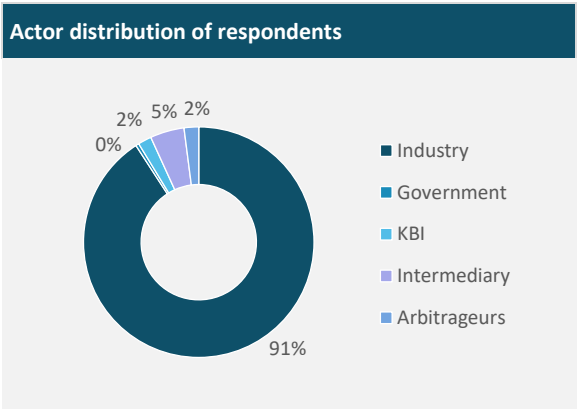


Figure 8 below depicts the ownership structure of the firms surveyed, which is 100% domestic as no foreign-owned firm participated in the survey.

FIGURE 8: Ownership structure of firms

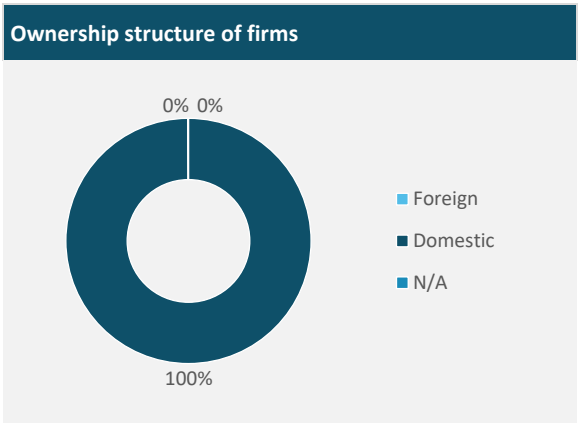


FIGURE 9: Size classification

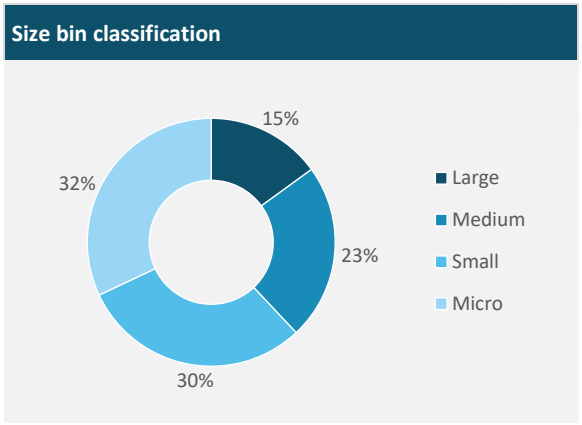


Figure 9 below shows the size classification of the firms surveyed. It is important to know the size of firms that participated in the survey as it can determine the level of innovation, internationalisation, and adoption of emerging technologies, etc. It can be seen that the majority of the firms surveyed belong to the micro size category (32%), closely followed by small (30%) and medium size firms (23%). Large size firms constituted the smallest percentage (15%) of the total firms surveyed.

The industry actor group is made up of 18 own brand manufacturers (OBM) (2%) and 1180 other contract manufacturing firms (98%). All KBI respondents are universities. Subsequently, Figure 12 shows that intermediaries are mainly composed of public institutions supporting technical change (ISTCs), incubators (academic, corporate/private and government) and industry associations. Arbitrageurs are composed of banks and venture capital firms while the government comprises both central and state governments and the majority representation was from state government agencies, outlined in Figures 13 and 14, respectively.

FIGURE 10: Industry – Affiliation

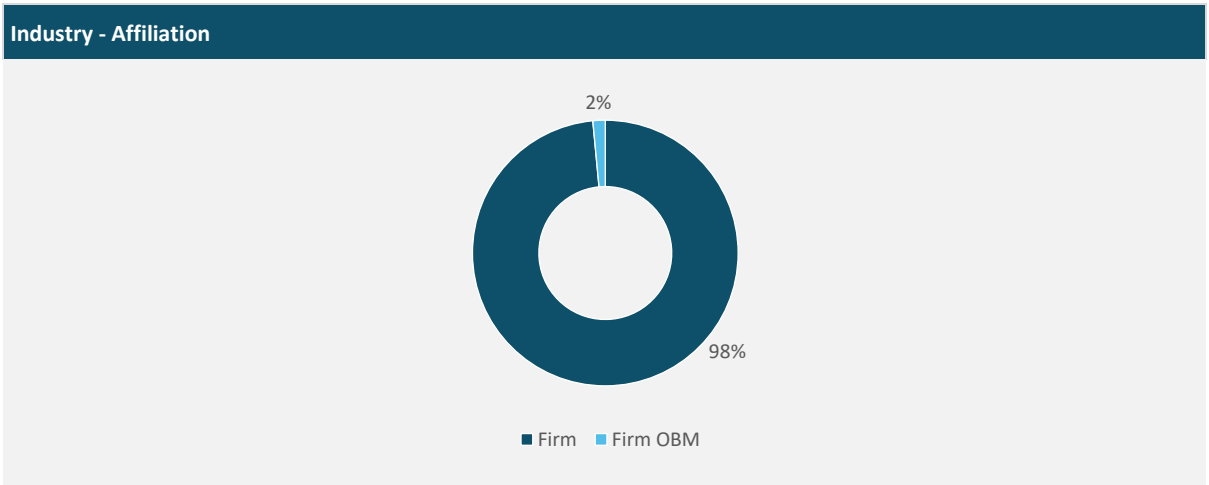


FIGURE 11: KBI – Affiliation

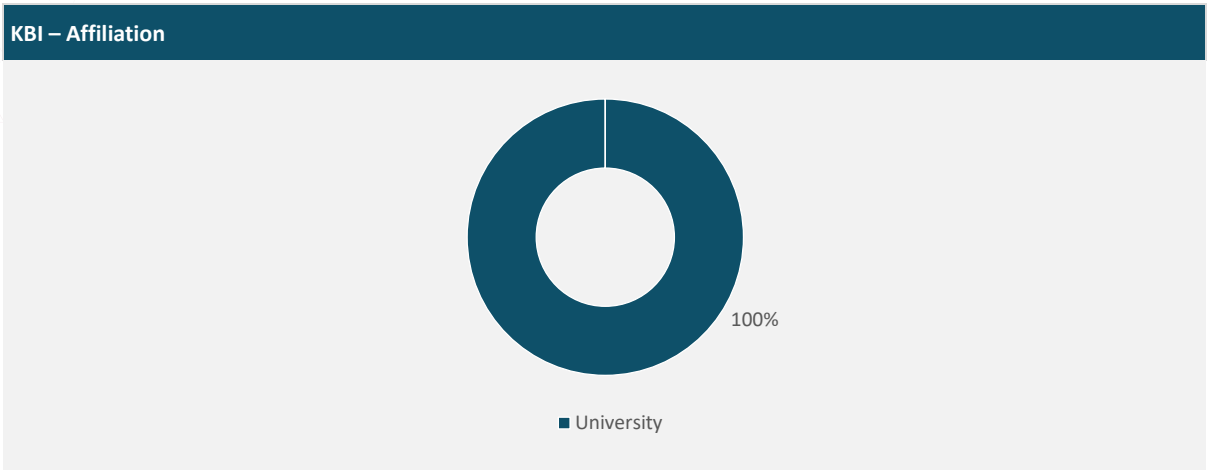


FIGURE 12: Intermediary – Affiliation

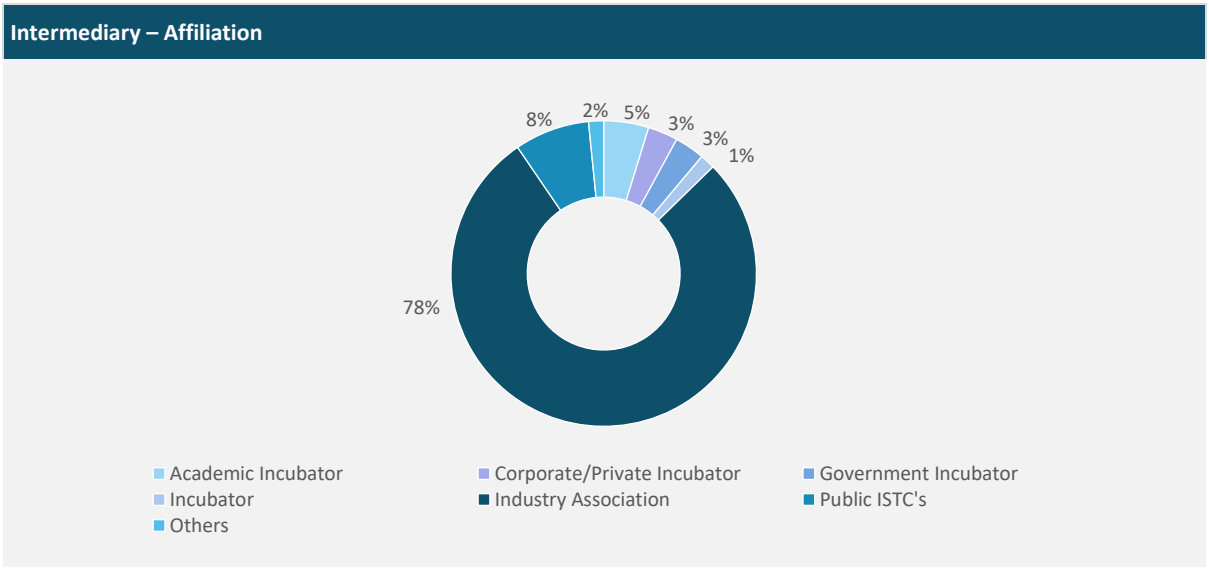


FIGURE 13: Arbitrageur – Affiliation

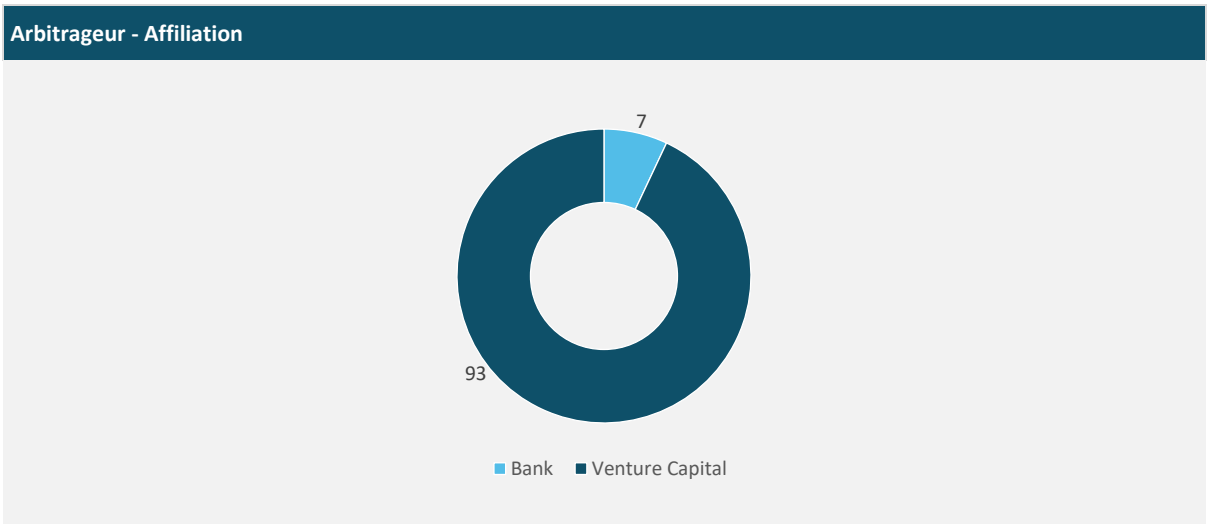
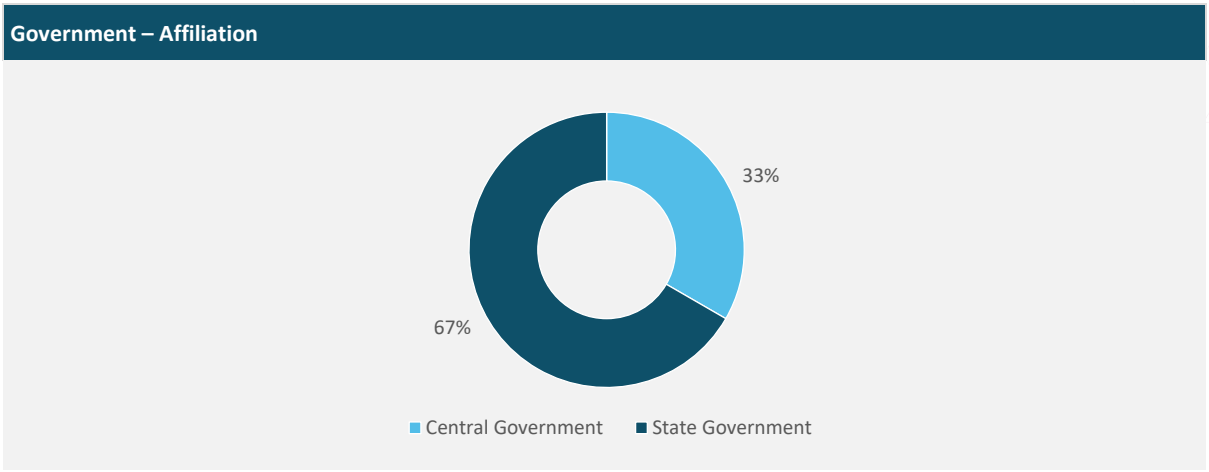
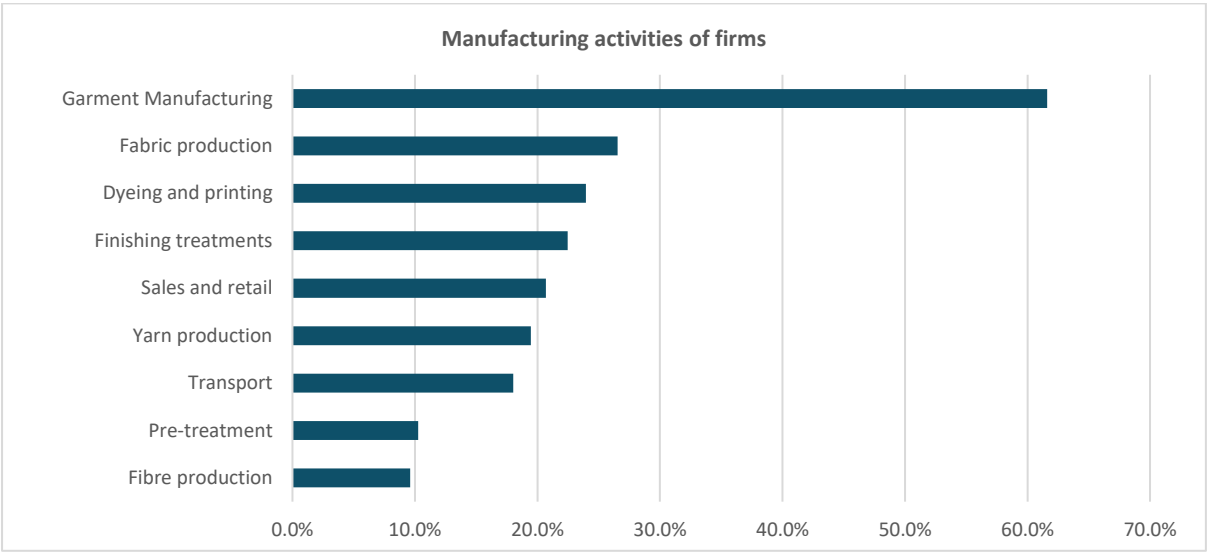


FIGURE 14: Government – Affiliation



The firms that participated in the survey are from different segments of the diverse textiles and garment industry Figure 15 depicts the types of manufacturing activities of the firms surveyed.

FIGURE 15: Manufacturing activities of firms



The lion's share of firms surveyed (62%) are involved in garment manufacturing while 27% of the firms are into fabric production. Furthermore, 24%, 22%, 21%, 19% and 18% of the firms are involved in dyeing and printing, finishing treatments, sales and retail, yarn production and transport. Figure 15 also shows that 10% of the firms surveyed are involved in pre-treatment and about the same percentage are involved in fibre production.

6.2 Linkages

Before the issue of the linkages between the actors in the ITASSI 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.

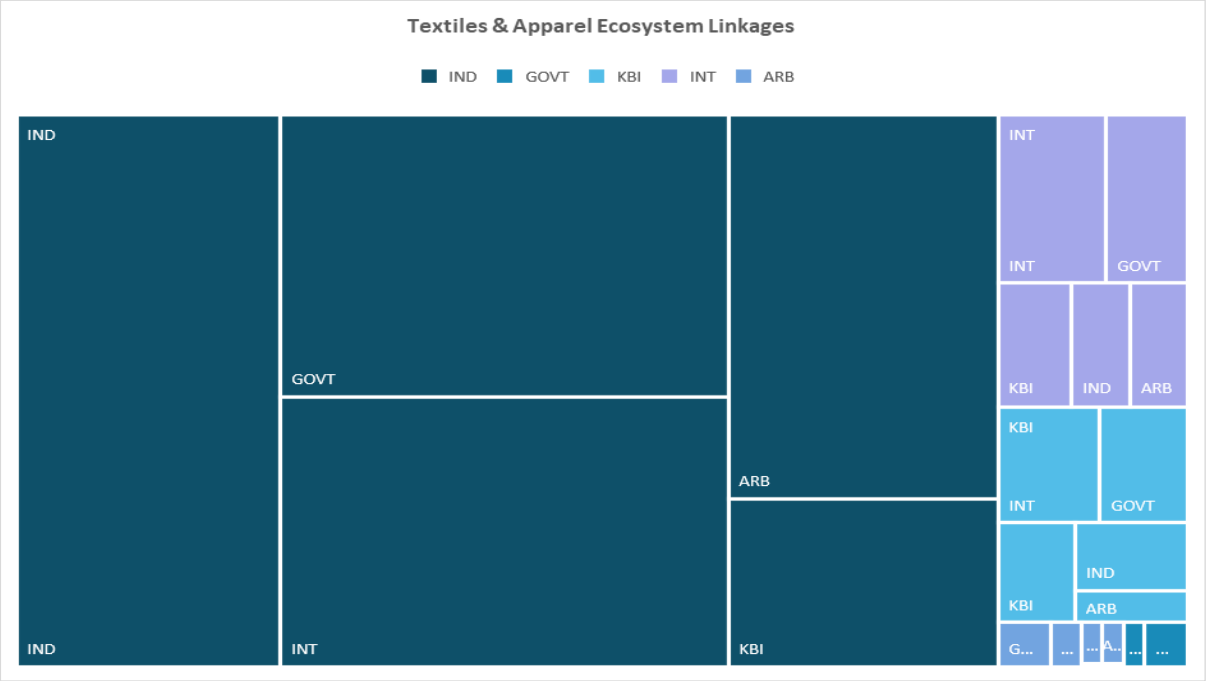
Type of Linkage

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.

It can be seen from Figure 16 that the majority of relationships are in proportional terms between the actors in the sectorial system of innovation. Firstly, in terms of the number of respondents, the actors who participated (in order of magnitude) are industry, intermediary, knowledge-based institution, followed by arbitrageurs and financial institutions. Industry actors have the lion's share of interactions with themselves and the government; Intermediaries mostly interact with themselves, and knowledge-based institutions primarily interact with intermediaries and government. Financial institutions and arbitrageurs primarily interact with the government and the government agencies interact with themselves and industry.

FIGURE 16: Ecosystem relationships



Sankey diagrams (refer to Figures 17, 18, 19, 20 and 21 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 17 below highlights the industry intra- and inter-linkages.

Intra-relationships

With respect to industry actors, the major intra-relationships are user-producer relationships in the form of contract buyer and supplier and formal and informal meetings. The user-producer relationships related to the production process, given the size representation of firms in the sample, show that large firms are involved in fibre production whereas MSMEs are involved in yarn/fabric/garment manufacturing.

Knowledge transfer through formal and Informal meetings takes place in the form of B2B platforms and conferences and exhibitions such as the International Convention on Colorants (COC) organised by the Dyestuffs Manufacturers Association of India (DMAI), where all reactive dyes manufacturers and exporters meet.

Formal meetings also 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 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 can greatly boost innovation (Grimpe and Hussinger, 2008).

BOX 1: Tiruppur - The undisputed knitwear capital of India.

Objective

Tiruppur is the largest knitwear cluster of India that was established to promote lean manufacturing practices and help the industrial units increase competitiveness. It has emerged as a leading export cluster in knitwear.

Approach

Located 60 km east of Coimbatore district of Tamilnadu - Tiruppur, which was once an agricultural town, has emerged as the knitwear capital of the country in the past three decades. It is the export hub of knitted garments in India accounting for 90% of the country's cotton knitwear exports and has built its presence in Europe, US, Australia and Canada. It is also a highly connected cluster of specialised individual units which together convert cotton to knitwear products.[59] Tiruppur is home to textile production worth INR 30,000 crore every year. With nearly 10,000 garment manufacturing hubs employing over 600,000 workers, out of which about 65% are semi-literate women from rural areas who make hosiery, knitwear, casual wear and sportswear.[60] In 1985, Tiruppur was exporting INR 15 crore worth of textile products. In the year ended March 2022, Tiruppur has clocked exports worth INR 33,525 crore accounting for 54.2% of India's textile exports in FY22.[61]

Although special industrial parks have been developed in Tiruppur to support the industry, Nethaji Apparel Park, Tiruppur Export Knitwear Industrial Complex, SIDCO Industrial Estate and J.S.Apparel Park are a few that are operational. Nethaji Apparel Park has 53 companies manufacturing knitwear for exports. World's largest retailers such as Nike, Walmart, Primark, Adidas, Switcher, Polo Ralph Lauren, Diesel, Tommy Hilfiger, M&S, FILA, H&M, C&A, and Reebok import textiles and clothing from Tiruppur. Formation of Tiruppur Exporters Association (TEA) in 1990 is considered a key triggering factor for Tiruppur attaining global fame.[62] It was established exclusively for exporters of cotton knitwear who have production facilities in Tiruppur. Tiruppur is also emerging as a sustainable sourcing destination for knitwear as it has already implemented Zero Liquid Discharge and made investment for production of non-conventional energy, wind and solar.

Outcomes

The union government is planning to set up 75 Tiruppur-like textile hubs which will not only support textile exports and ensure inclusion of sustainable technology but also generate huge employment opportunities, particularly for women and those from the marginalised sections.

[59] Sourced from: https://www.econ-jobs.com/research/52329-The-Emergence-of-Tirupur-as-the-Export-Hub-of-Knitted-Garments-in-India-A-Case-Study.pdf
[60] Sourced from: https://apparelresources.com/business-news/manufacturing/learn-tirupur-model/
[61] Sourced from: https://government.economictimes.indiatimes.com/news/governance/centre-plans-to-create-75-textile-hubs-like-tamil-nadus-tiruppur-union-minister-piyush-goyal/92484482
[62] Sourced from: https://www.indiantextilemagazine.in/tirupur-garment-exports-to-touch-rs-40000-cr-in-3-years/

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 trainings, as recipients of funding, recruitments and placement, trademarking, and licensing agreements.

Direct communication between industry and government can be seen in relation to the "Scheme for Integrated Textile Parks" (SITP) which was launched in 2005. The objective was to encourage private investments and employment generation in the textiles sector by facilitating world-class infrastructure for common facilities, such as roads, water supply treatment and distribution networks, power generation and distribution networks, effluent collection treatment and disposal systems, design centres, warehouses, first aid centres, etc. The initiative has had a slow level of implementation and to overcome many of these challenges, regular meetings are held in the Ministry of Textiles with various stakeholders and state government representatives.

Within the context of knowledge dissemination through seminars and training, the central government of India has launched the "SAMARTH Scheme for Capacity Building in Textile Sector" (SCBTS). The objectives of the scheme are to provide a demand-driven, placement-oriented skilling programme to incentivise the efforts of the industry in creating jobs in the organised textile and related sectors to promote skilling and skill upgradation in the traditional sectors through respective sectorial divisions/organizations of the Ministry of Textiles. The InduTech biennial conference focusing on industrial textiles is an example for tacit knowledge transfer. It is hosted by the Department of Textiles, PSG College of Technology along with industry partners (InduTech). The objective is to showcase the key innovations and opportunities arising out of academic and industrial research in industrial textiles. In addition, national level events such as the National Conclave of Technical Textiles, Global Textile Summit 2022, Surat International Textile Expo (SITEX) are also organised by industry and intermediaries on a regular basis. Such events provide an opportunity for all the leading manufacturers to showcase their developments and innovations and provide a platform for MSMEs to interact with the buyers and suppliers to diversify and expand their operations in the existing market.

Another example of how knowledge transfer is occurring between industry and intermediaries can be seen by manufacturers with their industry associations is the Ahmedabad Textile Industry's Research Association (ATIRA) conducting technical training on composite textiles for TVS Motors. Apart from research and development, it offers consultancy, training, testing, and calibration services. The ATIRA has 8 Science Technology Divisions, 11 laboratories / service centres and a regional centre at Indore, Madhya Pradesh.

With respect to arbitrageurs and financial institutions, the majority of firms reported relationships as recipients of funding. The government is assisting the industry through the "Technology Upgradation Fund Scheme" (TUFS) which provides for 5% interest reimbursement on the loans/finance raised from designated financial institutions such as the Small Industries Development Bank of India (SIDBI), Industrial Finance Corporation of India (IFCI), Industrial Development Bank of India for benchmarked projects of modernisation. These financial institutions have been designed as nodal agencies for large and medium small-scale industry and jute industry respectively. They have co-opted 148 leading commercial banks/cooperative banks and financial institutions like state finance corporations and state industrial development corporations. (Ministry of Textiles, 2003).

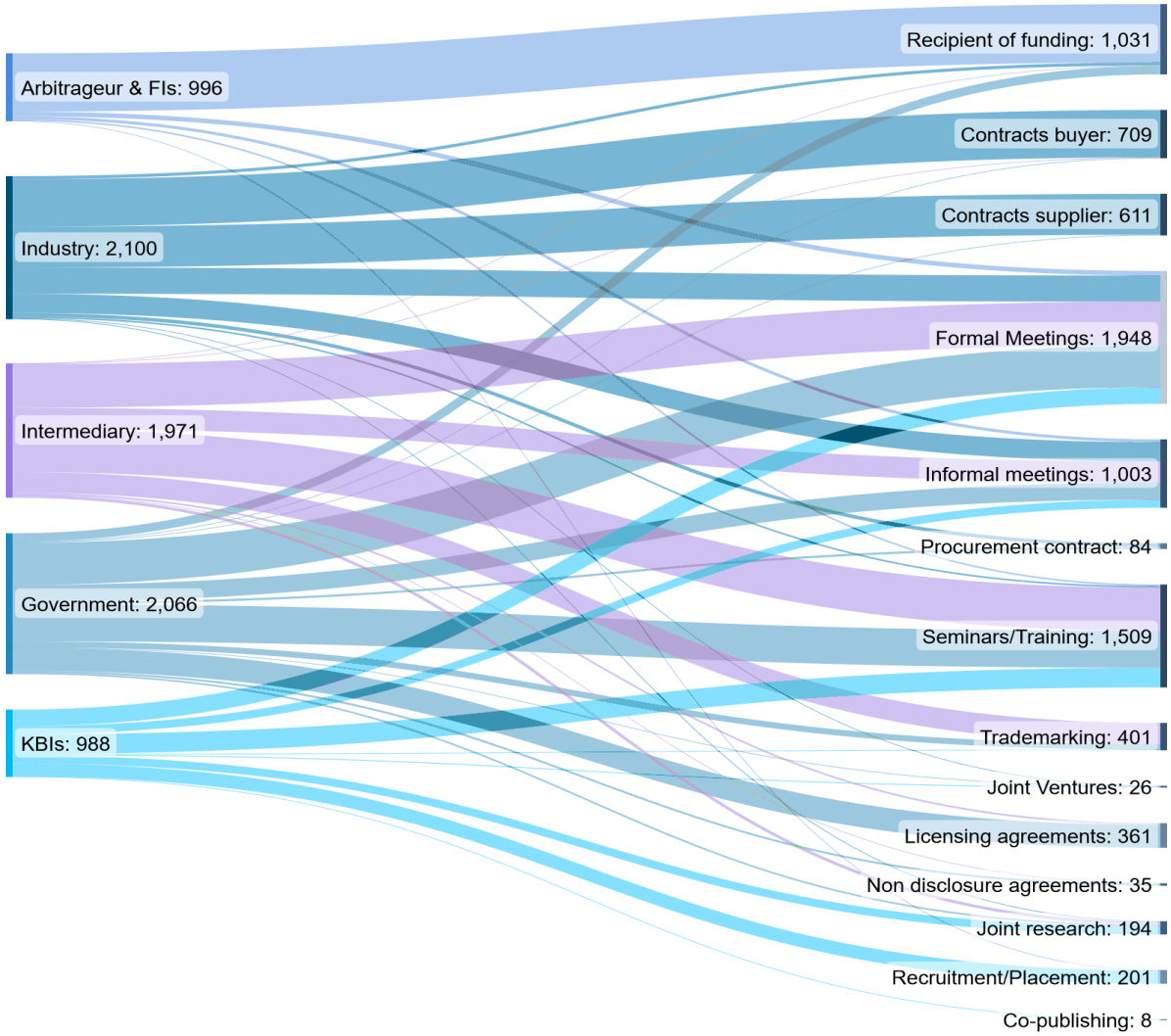
In terms of recruitments and placements, the benefits are clear that industrial placement schemes can facilitate student learning from theoretical to the practical and make them more 'industry ready' (Wandahl & Faber, 2016). In addition, the benefits of fostering such industry-KBI interaction include the ability to guide and improve curriculum development (Arlett et al., 2010, Wandahl et al., 2011). The indication being that formal mechanisms need to be bolstered. An example where industry sees KBIs as a source of skilled human capital for the textiles sector is evidenced by campus placements from leading institutes, for example, Arvind Ltd with L.D. College of Engineering, Ahmedabad. However, in the case of many Indian institutions, personal relationships of the academic with industry, rather than that of the institution are strong drivers in the success of the placement process[63].

In the case of licensing agreements, the Defense Research and Development Organization (DRDO) has transferred the technology of a bullet proof jacket to M/S MKU Limited, Kanpur for manufacturing for the Indian army and paramilitary forces personnel (DRDO, 2014). In the case of trademarks, Geographical Indications (GI) helpdesks have

[63] Perkman et al., First, academic engagement is practiced primarily by scientifically productive individuals, suggesting it is complementary to, or even instrumental for, academic research activities. Second, academic engagement is positively correlated with mobilising research funding and resources. Third, academic engagement appears, as compared to commercialisation activities, to be more driven by autonomous individual motivations and characteristics and less influenced by embedded university characteristics: https://www.sciencedirect.com/science/article/pii/S004873332030189X

been set up at each weavers service centres to address the issues related to GI products and to promote GI in the handloom clusters. So far, 65 handloom products and 6 product logos are registered under this "GI Act" (Ministry of Textiles, 2019). [64]

FIGURE 17: Industry relationships



6.2.2 Knowledge-Based Institutions

Figure 18 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 international conferences such as that for "Industrial Textiles – Products, Applications and Prospects" – InduTech – 2016 organised by PSG College of Technology in collaboration with HOF University of Applied Science, Institute for Frontier Materials, Australia and Northwest Composites Centre - University of Manchester, UK.

With respect to joint research and co-publishing, IIT Delhi engages in collaborative research with the Jute and Fibre Technology, University of Calcutta, Uttar Pradesh Textile Technology Institute and Dr. B. R. Ambedkar National Institute of Technology, Jalandhar. However, externalisation of knowledge in the form of co-publishing is generally associated with the National Assessment and Accreditation Council (NAAC) under the pillar of research

[64] Sourced from: https://cpcb.nic.in/categorization-of-industrial-sectors/

innovation and extension, or the National Institutional Ranking Framework (NIRF) under the pillar of research and professional practice.

Inter-relationships

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

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

Like the "Upgrading the Skills and Training in Traditional Arts/ Crafts for Development (USTTAD) Scheme", the Ministry of Minority Affairs has entrusted a project to the National Institute of Fashion Technology (NIFT) with the objective of training and upgrading skills of craft persons belonging to minority communities thereby preserving the traditional ancestral arts/crafts being practiced by them.

Within the innovation process, intermediaries are important organizations in mitigating systemic failures (Sutthijakra and Intarakumnerd, 2015). One of their key roles is knowledge dissemination to their members. The level of tacit knowledge transfer between KBI's and industry associations can be seen in the example of the Association of Man-Made Fibre Industry India (AMFII) collaborating with NIFT, Delhi on the market promotion of viscose fibres.

With respect to joint research, the NIFT has recently undertaken a project for the development of a national knowledge portal titled "The Repository -- Indian Textiles and Crafts" (RTC) for the Ministry of Textiles under the "Craft Cluster Initiative" of the "National Handicrafts Development Programme" (NHDP) of DC (handlooms and handicrafts). The RTC has been planned as an online resource network for the textile, clothing and craft sectors of India[65]. Another example is the Trend Insight and Forecasting Lab sanctioned by the Ministry of Textiles, Government of India under the R&D scheme to develop an AI-based deep learning model enabled to forecast fashion directions for India. Over a span of three years, this initiative will create its first ever indigenous forecast for the Indian fashion and retail industry. To date, no such services are available in India that interpret Indian tastes and preferences and map fashion aesthetics of the country to put India on the global map of technology-enabled fashion. The project is expected to benefit a wide range of industries in clothing and textiles. Joint research involving intermediaries is exemplified by the NIFT-TEA Atal Incubation Centre, Tiruppur and Society of Dyers and Colorist joint research on salt-free dyeing innovations. With respect to intelligent textiles[66], Troop Comforts Limited (TCL), a Government of India enterprise under the Ministry of Defense with headquarters at Kanpur, signed an MoU with the country's leading research institution IIT Delhi to develop smart protective clothing for the Indian Security Forces. The flexibility of informal communication is key to idea generation and innovation (McAlpine, 2017).

A good example of user-producer relationships, procurement contracts and recipients of funding is the Centre of Excellence for Industrial Textiles (PSG TECHS COE INDUTECH), under the PSG College of Technology, offering consultancy and testing services[67] to industry and through tenders[68] and inviting reputed manufacturers for the supply of lab equipment and machinery which acts as a rents generation model.

In relation to recruitment and placements there are instances, where large firms have tie-ups with local universities for the steady flow of skilled human resources. In reverse, industrial practitioners' representation as faculty members within knowledge-based institutions is also important, as seen with the "IIT Delhi Professor of Practice" (PoP) and "Adjunct Professor of Practice" (APoP) schemes which encourage the recruitment of industry professionals into academics (IITD, 2019). The initiative enables students to learn from experienced individuals regardless of their age, educational background or profession and add broader perspectives to their academic experience. These positions are of a fixed tenure and additional benefits to the institution include their ability to guide the curricula and keep it relevant and current to the sector (Kang et al., 2005).

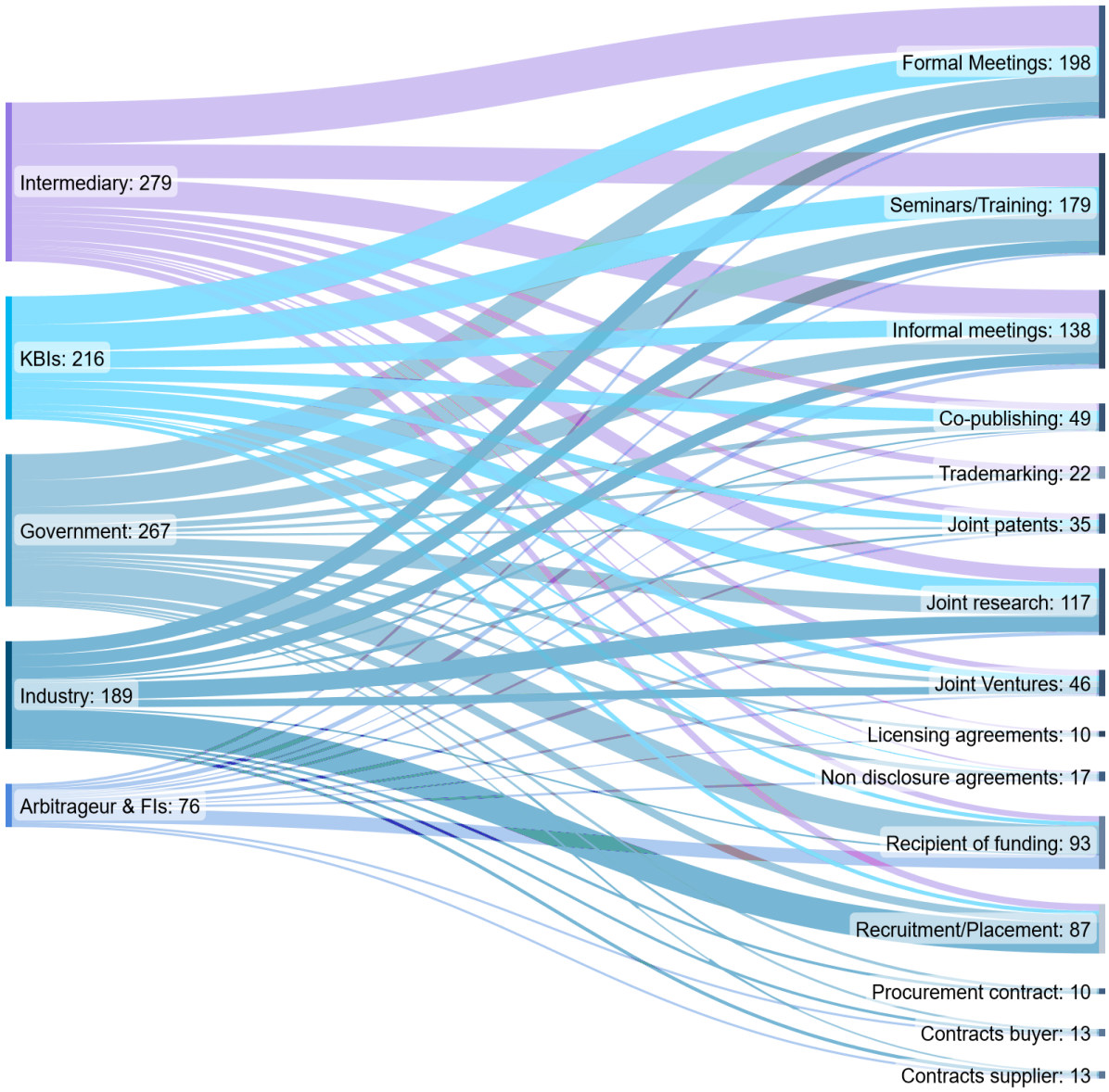
[65] Sourced from: https://www.nift.ac.in/sites/default/files/2022-09/TOR%20for%20RTC%20Project.pdf

[66] Intelligent textiles represent the next generation of fibres, fabrics and articles produced to respond in time. They can be described as textile materials that think and act for themselves. This means they keep us warm in cold environments or cool in hot environments or provide us with considerable convenience in our normal day-to-day affairs. Intelligent textiles are not confined to the clothing sector alone. They are used in protection, safety, added fashion and convenience. The most important intelligent materials at present are classified as 1) Phase change materials, 2) Shape memory materials, 3) Chromic materials 4) Conductive materials and 5) Electronics incorporated textiles.

[67] Sourced from: https://www.psgtech.edu/Research/Consultancy%20work%20completed.pdf

[68] Sourced from: https://www.psgtech.edu/coeindutech/Tender%20FIC%204%20document%20with%20corrigendum%20%201.pdf

FIGURE 18: Knowledge-based institution relationships



6.2.3 Government

Figure 19 highlights the government intra- and inter-linkages.

Intra-relationships

The main intra-linkages reported are formal and informal meetings, seminars/trainings, joint research, recipients of funding and co-publishing.

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 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). Beyond policy, the Ministry of Water and Ministry of Textiles have been collaborating for the application of geotextiles in strengthening dams from water seepage. A similar example is “Technology Development”, the Department of Science and Technology and the Ministry of Textiles joint project on water-less dyes.

In the case of co-publishing and seminars/trainings, the Controller General of the Patents Office, Designs and Trademarks (DPIIT) conducts IPR awareness programmes under the “National Intellectual Property Awareness

Mission" (NIPAM) and also publishes various journals like the "Patent Journal", "Trademark Journal", "GI Journal" as well as newsletters[69].

A clear example of co-publishing is the development of the "Practice Manual for Use of Technical Textiles in Water Resources Works" by the Central Water and Power Research Station[70].

Funds flow between government entities including the central government providing financial assistance to state governments for the setting-up of a "State Cluster Development Programme" to support soft and hard interventions in clusters with limited funding support. In order to strengthen this activity, this component would provide co-funding of the Common Facility Centre (CFC) projects of the State Cluster Development Programme on a matching share basis. The Government of India funds would be limited to a state government share of INR 5 crore, whichever is lower. The government assistance would be 90% of the project cost not exceeding INR 5 crore in respect of CFC projects in northeast/hilly states, island territories, aspirational districts/left wing extremism affected districts, as well as for projects where beneficiaries are SC/ST/women-owned enterprises, as per the scheme guidelines of the State Cluster Development Programme.

Inter-relationships

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

With the enactment of the "Textiles Committee Act" in 1963, the Cotton Textiles Fund Ordinance was replaced, and the Textiles Committee was composed of members comprising senior Government Officers and prominent representatives from the textile industry and trade associations. This was established as an apex body for policy and a statutory body for ensuring the quality of textiles and textile machinery and for looking after matters connected therewith. The functions of the committee are to ensure by such measures, as it thinks fit, standard qualities of textiles, both for the internal market and for export, and the manufacture and use of standard qualities of textile machinery. The committee has, in its ambit, a vast range of functions and activities like scientific, technological and economic research, export promotion, inspections, testing, establishment of laboratories and test houses, collection of statistics for market study and research and rendering advice on all matters relating to the development of the textile industry and the production of textile machinery.

Flow of government funds is traditional in nature as for higher education and in the form of R&D grants. A unique example is that of SMITA Research Lab at IIT Delhi which, with the generous funding from the Ministry of Textiles, Ministry of Education, Department of Science and Technology and industry partners, has been able to establish state-of-the-art research facilities that are unique in the country and can be used for the expeditious development of new smart technologies.

In the case of arbitrageurs and the flow of funds and knowledge dissemination, the "Tex Venture Fund" from SIDBI is an example where the objective is to contribute to the development of the powerloom and related textiles sectors. Another case is the "SIDBI Venture Capital Fund Ltd." (SVCL). SVCL invests on behalf of the Ministry of Textiles in the form of equity in MSMEs to kick start an enterprise or for expansion. As a part of these activities, there are integrated outreach functions in the form of seminars and awareness building. In addition, non-disclosure agreements (NDAs) are commonplace in the transactional relationships between system actors as the motive is to control the use and disclosure of confidential information. It is particularly common in the case of confidential and proprietary information or offers to potential partners and investors (Sharma and Shrivastav, 2020).

Similarly, Tamil Nadu State Government has facilitated the "Tamil Nadu Emerging Sector Seed Fund" (TNESSF)[71] - category, a venture capital alternate investment fund with the objective to invest in startups and undertakings in the sunrise/ emerging sectors, textiles and garments being articulated in the "Tamil Nadu Industrial Policy" (Gov Tamil Nadu, 2021). The purpose is to identify and invest in "bankable" startups and emerging sector companies to add alpha to the business in the form of financial and non-financial support.

Government's collaboration with the intermediaries is mainly focused on the application and usability of geotextiles and agrotextiles. The Ministry of Textiles in collaboration with the Indian Chamber of Commerce (ICC) organised the Technical Textiles Conference on 23rd August 2022 in Imphal, Manipur. Geotextile products which are used in the ministry projects include: woven and non-woven geotextiles, biaxial and multiaxial geogrids, geocells, geonets and geocomposites, (e.g., for reinforcement for pavements, stress-relief for slopes, barriers, separation,

[69] Sourced from: https://ipindia.gov.in/
[70] Sourced from: http://jalshakti-dowr.gov.in/sites/default/files/Technical_Textile_Practice_Manual.pdf
[71] Sourced from: TNIFMC - Tamil Nadu Infrastructure Fund

filtration, drainage, protection and stabilisation). Most of the geotextile products are manufactured in India. The Ministry of Road Transport and Highways is also conducting studies related to geosynthetics, geogrids, geonets, and natural fibres with premier institutes including IIT Hyderabad and IIT Chennai. In November 2022, the Ministry of Textiles cleared 20 strategic research projects worth INR 74 crore in the areas of agrotextiles, speciality fibre, smart textiles, activewear textiles, strategic application, protective gear and apparel, and sports textiles. These strategic research projects fall under the flagship programme "National Technical Textiles Mission". According to the ministry press release, various leading Indian institutes including IITs, government organizations, research organizations, among others, participated in the session which cleared these projects[72]. Such collaborations between industry, academia and government are required for widening the utilisation of geotextiles and agrotextiles in India[73].

BOX 2: Innovation Voucher Program

Objective

Tamil Nadu launched the first of its kind "Innovation Voucher Program" (IVP) in the country to offer grant-in-aid for supporting and promoting research and innovation among startups and MSMEs.

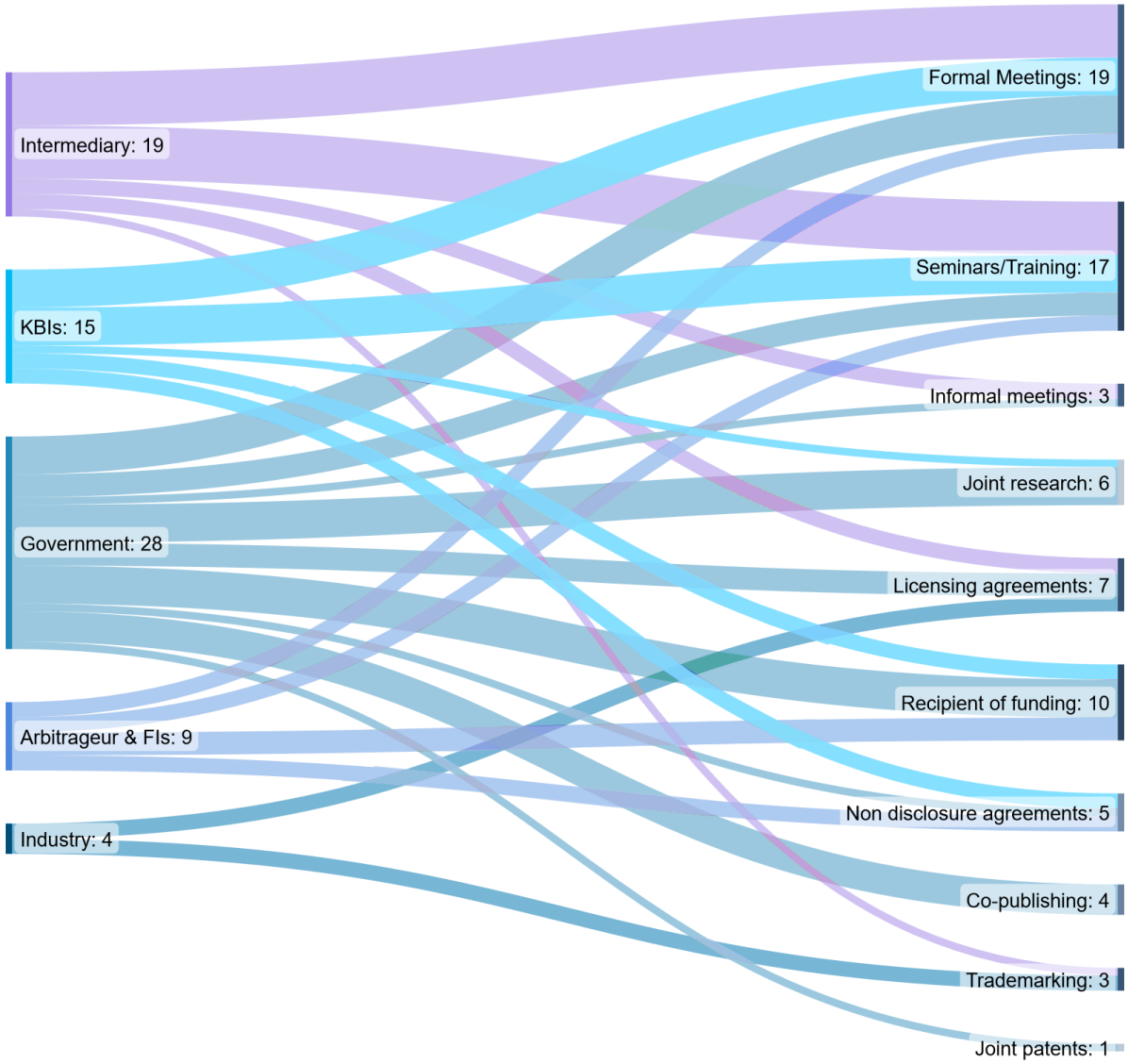
Approach

The grant-in-aid is positioned to encourage startups and MSMEs to take up research and innovation to address the practical needs of the industry, largely micro and small industries.

Modelled on international best practices, Tamil Nadu also held pilot projects on innovation vouchers over 2012-15, with the support of Deutsche Investitions und Entwicklungsgesellschaft (DEG), Germany for fostering interaction, exploration, access, and improved performance of micro and small firms[74]. The Government of Tamil Nadu, under its Entrepreneurship Development and Innovation Institute launched the IVP in 2018 to offer financial support to MSMEs to increase their innovation capacity [75]. The IVP is open to all MSMEs in the state and are awarded on a competitive basis through open application. It is anchored through the support of its knowledge partners including key national research institutions such as CECRI, CFTRI, IIFPT, CLRI, CIPET, research departments of government recognised universities or institutions for higher learning, research labs of MNCs or other large industries, product design consulting firms and design labs. The two-pronged voucher programme offers up to INR 2 lakh crore under "Voucher-A" to cover upto 80% of the research project costs, and under "Voucher-B" up to 50% of support for market entry is covered with vouchers worth INR 5 lakh crore. The Voucher-A is positioned to support any activity for innovation potential analysis, that can include market research, technology feasibility studies, design/material studies, R&D, etc; while Voucher-B supports expenditure to meet product designing, prototyping, engineering, testing and also project management. The IVP aid support is made efficient and time-bound with voucher validity mandated to 12 months since its release of the first installment by Entrepreneurship Development and Innovation Institute - Tamil Nadu.

[72] Sourced from: https://www.livemint.com/news/india/textiles-ministry-clears-20-strategic-projects-worth-rs-74-crore-11667375405734.html
[73] Sourced from: https://www.pib.gov.in/PressReleseDetailm.aspx?PRID=1853905
[74] Sourced from: https://www.giz.de/en/downloads/giz2016-en-GIZ Private Sector Development Newsletter No.9.pdf
[75] Sourced from: http://cms.tn.gov.in/sites/default/files/go/msme e 17 2018.pdf

FIGURE 19: Government relationships



6.2.4 Intermediary

Figure 20 highlights intermediaries intra- and inter-linkages.

Intra-relationships

The main intra-linkages reported are formal and informal meetings along with seminars/training and trademarking. This indicates high tacit knowledge transfer between intermediaries which, as was previously elucidated, is crucial for idea generation and sharing. An example of this is the Joint Technological Conference organised by 4 industry research associations - Ahmedabad Textile Industries Research Association (ATIRA), North India Textile Research Association (NITRA), Bombay Textile Research Association (BTRA) and the South India Textile Research Association (SITRA). One such example is the joint conference on protective and automotive textiles, which focused on: the development of value-added products from natural fibres; product development using banana fibres, blended yarn, water consumption reduction and a proper mercerization process to control the consumption of caustic soda. This highlights that there is a great degree of communication amongst industry associations for the benefit of the sector. They are seen to work collaboratively, rather than competitively.

Another example of this collaboration is the Centre of Excellence for Medical Textiles - the South India Textile Research Association (SITRA) that is involved in standard formulation with BIS and international bodies and engages in R&D consultancy with the National Jute Board and has a joint venture/project with the Indian Space Research Organization (ISRO)[76].

[76] Sourced from: Incubation Centre for Medical Textiles in India. Medical Textile Consultancy Services - SITRA, Coimbatore.

Inter-relationships

With respect to inter-relationships, the most prominent are seminars/training, formal and informal meetings, recipients of funding and joint research.

Formal meetings, seminars and training would underscore the function of 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. Formal communication and information exchange linked to funding with government can be seen in the "International Co-operation Scheme" by the Ministry of MSMEs. This scheme provides financial assistance to the industry associations for the Deputation of MSME Business Delegations to foreign countries with an objective of exploring new areas of technology infusion and upgrading, facilitating joint ventures, and improving the market of MSME products. The Tamil Nadu Industrial Investment Corporation Ltd funding NIFT-TEA Atal Incubation Centre exemplifies the transfer of funds.

In addition, knowledge dissemination related to the financial aspects of the sector were highlighted by CRIF High Mark Credit Information Services Pvt. Ltd, an RBI-approved credit bureau in India with the Small Industries Development Bank of India (SIDBI) jointly publishing "Industry Spotlight: Indian Textiles and Apparels Industry".

Intermediaries engaging in knowledge generation and dissemination with knowledge-based institutions is embodied by the Centre of Excellence for Protech Segment of Technical Textiles[77] jointly set-up by IIT Delhi and the Northern India Textile Research Association (NITRA), Ghaziabad with the financial assistance of the Ministry of Textiles. The objective of the centre is to promote the segment of technical textiles and to provide infrastructural support and facilities in one place for the convenience of its manufacturers.

The Apparel Export Promotion Council has launched the "Apparel Industry Sustainability Action" (AISA) to evaluate the existing status of the Indian apparel industry, to encourage wider penetration of these measures amongst the MSMEs, to hand hold these units with demonstrations and solutions, to enhance the brand visibility of sustainable companies on a global platform and to brainstorm necessary policy focus towards the wider and smooth adoption of sustainability measures amongst Indian garment units at large[78].

Following is the example of the Bombay Textiles Research Association (BTRA) which undertakes projects sponsored by the government as well as industry/public sector undertakings like the Indian Oil Corporation Ltd., BTRA has also licensed its own developed products for bulk manufacturing and supply to industry and also publishes survey reports, technical reports and research project reports. BTRA has licensed numerous products for bulk manufacturing and supply as a part of its know-how and technology supply function. In the area of knowledge dissemination, BTRA has a great number of peer-reviewed journals and publications. Similarly, NITRA undertakes joint research sponsored by the Ministry of Textiles for the setting-up of a common effluent treatment plant (CETP) at Bhuj[79]. Technology of the NITRA Electronic Drape Meter was transferred to M/s. Dinu Technologies, Coimbatore which was given license to manufacture it[80].

[77] Sourced from: https://home.iitd.ac.in/uploads/mou/NITRA_MOU.pdf
[78] Sourced from: https://apparelresources.com/business-news/sustainability/apparel-industry-sustainability-action-aisa-launched/
[79] Sourced from: http://www.nitratextile.org/pdf/R&D%20projects%202020-21.pdf
[80] Sourced from: http://www.nitratextile.org/instruments-developed.php

BOX 3: ITAMMA Technology Scouting Mission (industry intermediary for technology upgradation and innovation).

Objective

ITAMMA's technology scouting programme aims to improve productivity in textile machine manufacturing SMEs via technology transfer, upgradation and innovation and addressing international competition with respect to the sophistication and cost efficiency of machinery.

Approach

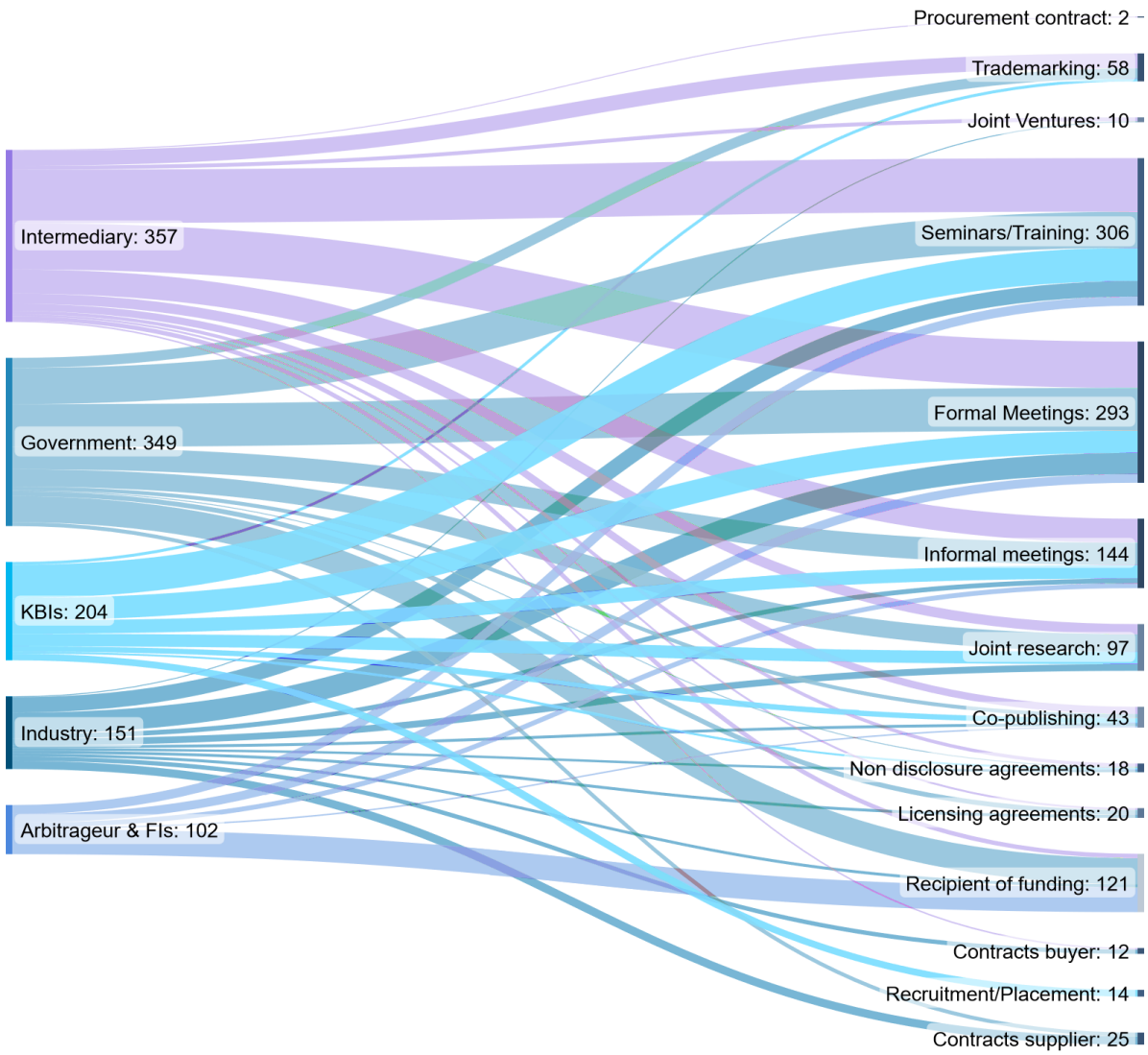
The Indian Textile Accessories and Machinery Manufacture Association (ITAMMA) is a key representation of SMEs in the Indian textile engineering and accessories industries, with strong advocacy on policies and institutional support to improve members' capacity to innovate and spur growth. Through a series of initiatives under its technology scouting missions, the ITAMMA has been spearheading technology transfer and upgradation among its members. The scouting mission is advised by a panel of 78 industry experts and the mission objectives are strengthened via MoUs with 37 textile research centres and associations in India and 17 international stakeholders.

It participates in key international textile machinery exhibitions and prepares technical reports to offer the members information on the latest technologies and innovations, and the scope of technology transfers and joint ventures. It has conducted several factory visits to establish collaborations with leading manufacturers, fabricators and service providers in textile engineering. Some of the key examples include Gold Seal Saar Gummi India and S K F Technologies (India) signing an MoU with SITRUST SIEMENS for virtual reality capacity building and the Petroleum Conservation Research Association (PCRA) on resource efficiency in textile machines, components and processes. It also drives industry-academia collaboration by providing opportunities to students to conduct pilot projects in manufacturing plants as a part of their theses. It has been supplemented by the ITAMMA's missions on technology awareness and dissemination, adaptation and marketing to achieve design awareness, ZED certifications, lean manufacturing schemes, reduction in waste generation, improve efficiency of raw material use and fuel use, among others.

Outcomes

The ITAMMA has several successful examples of technology upgradation, technology transfers and indigenous substitutions in textile machinery firms. Key examples include the "Mec Short Stretch Conversion Kit" developed for the ring-spinning frame in textile mills across India is an import substitute in textile manufacturing that improved production by 10% and reduced manufacturing costs, with paybacks within 6 months. These kits have an impact opportunity in affecting 43.13 million spindles across India. Another is the indigenisation of aluminum tubes, for the alucore cots used in spinning, that reduced the price by 50% and created great cost savings as per month 12,000 kgs of aluminum tubes are used. Similarly, indigenous oil tempered wire at half the price of imported components. Also, soft flow dyeing technology indigenisation resulted in 25–35 litres water/kg saving in fabric dyeing. This is of key importance as 60,000 tonnes of fabric is dyed annually in India.

FIGURE 20: Intermediary relationships



6.2.5 Arbitrageurs and Financial Institutions

Figure 21 highlights arbitrageur and financial institution intra- and inter-linkages.

Intra-relationships

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

For arbitrageurs and financial institutions to effectively stay on track with the market and assess, risk information flow is crucial. The Bank of Baroda's "Banking Beyond Tomorrow" Annual Banking Conference 2022, which focuses on strengthening financial inclusion, innovative technologies and new business models for digital banking, ESG finance and tackling climate change is a good example of this[81].

With respect to the recipients of funding, the Department of Refinance, National Bank for Agriculture and Rural Development (NABARD) provides co-operative banks and regional rural banks loans so as to improve credit flow at the ground level.

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 recipients of funding.

As previously highlighted, formal communication contributes to the process of sharing information,

[81] Sourced from: https://www.bankofbaroda.in/hi-in/-/media/project/bob/countrywebsites/india/content/media/press-releases/banking-beyond-tomorrow-annual-banking-conference-2022-22-07-2022-26-10.pdf

exchanging and developing ideas, as well as expressing disagreement, and managing conflict (Shasitall, 2022), however this mechanism indicates there is a structured approach with a focused agenda which is to be expected between the two actors. Formal channels of communication can be seen through mechanisms such as the State Level Bankers' Committee (SLBC), which was constituted in April 1977, as an apex inter-institutional forum to create adequate coordination machinery in all states, on a uniform basis for development of the state. SLBC is chaired by the Chairman/ Managing Director/ Executive Director of the Convenor Bank. It comprises representatives of commercial banks (including small finance banks, wholly owned subsidiaries of foreign banks, regional rural banks, payments banks, state cooperative banks, the RBI, and the NABARD), heads of government departments and representatives of financial institutions operating in a state, who come together and sort out coordination problems at the policy implementation level.

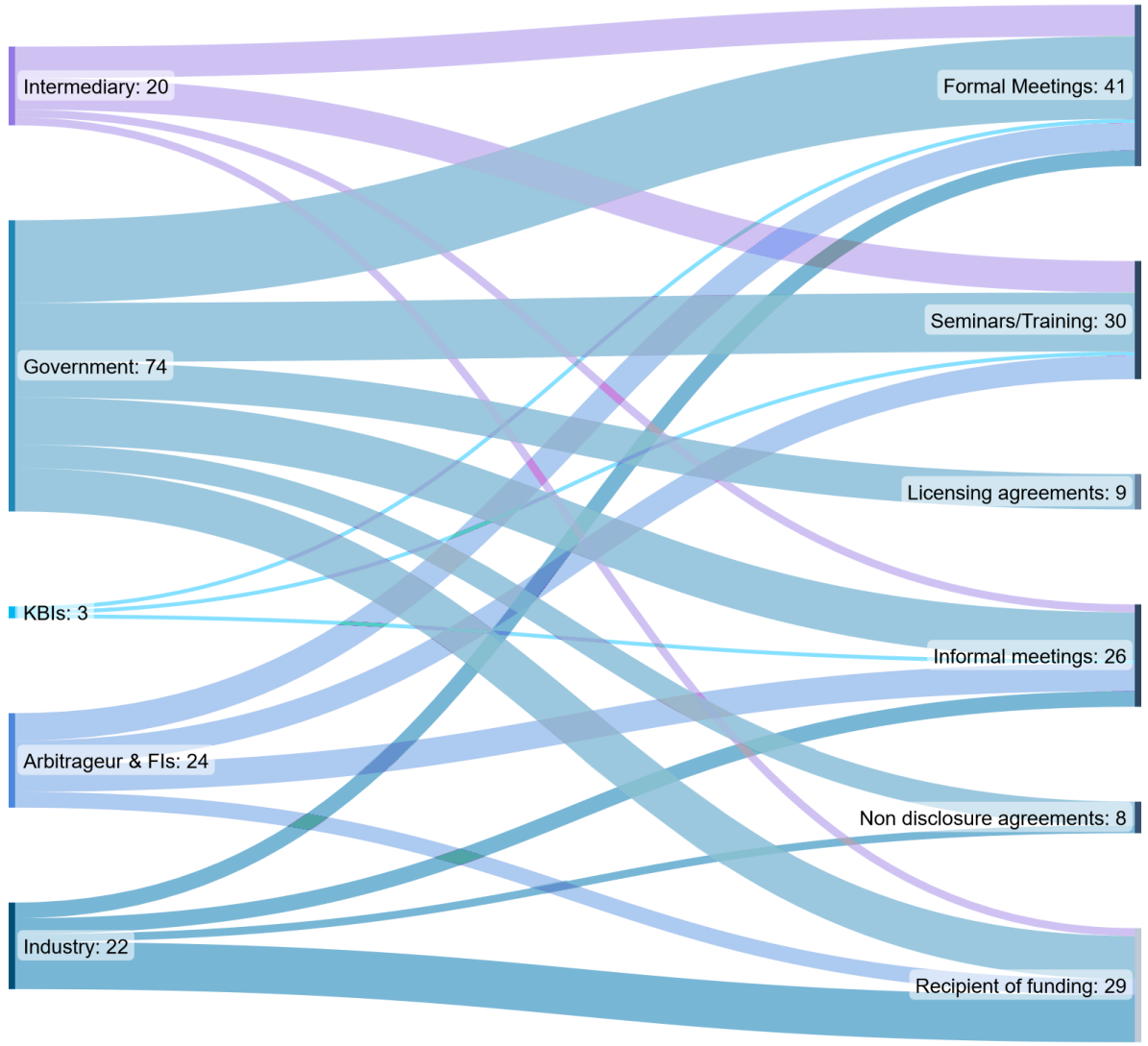
Formal and informal communication between arbitrageurs and financial institutions and government generally orient around investment policies. For example, the 4th Roundtable with Global Venture Capital Funds, was organised by the Department for Promotion of Industry and Internal Trade (DPIIT), Ministry of Commerce and Industry, to explore new sectors for investing, promoting and protecting the intellectual property created by the young Indian entrepreneurs, and to provide expertise to scale-up and explore greater capital infusion including risk capital.

Located in Hyderabad, the State Bank Institute of Innovation and Technology (SBIIT), an ISO 9001:2015 institute, was established in 1987 with KBI relationships and tacit knowledge transfer in mind. It is SBI's Apex Technology and Digital Training Institute specialised in IT-related training, R&D, innovation and e-learning[82]. With respect to knowledge sharing within universities, Abhivyakti 2020 is an annual startup showcase event, which witnesses the presence of more than 20 prominent venture capitalists and angel investors like Aavishkar Capital, Endiya Partners, SIDBI Ventures, IAN, 50K Ventures, Capala Ventures, Artha Ventures, etc. This helps sensitise young entrepreneurs and innovators as to what funding options may be available to them. Similarly, NIFT TEA College of Knitwear Fashion, Tiruppur (NIFT-TEA) and Atal Incubation Centre which is funded under the Atal Innovation Mission, NITI Aayog conduct several training programmes like the "Innovation Voucher Program", and "Online Faculty Training Programme on Entrepreneurship Development".

With respect to funding, the "Fund of Funds for Start-ups" (FFS) was introduced in 2016, for contribution to various alternative investment funds (AIFs) registered with the capital market regulator SEBI. The FFS, run by the state-controlled Small Industries Development Bank of India (SIDBI), has invested more than INR 9,400 crore in 86 AIFs (the regulatory term for PE and VC funds)[83]. With more of a focus on MSMEs, the Bank of Baroda is offering finance to textile units as a working capital requirement or for financing new projects[84].

[82] Sourced from: https://sbi.co.in/web/strategic-training-unit/sbiit-hyderabad
[83] Sourced from: https://economictimes.indiatimes.com/tech/funding/to-boost-startup-financing-government-offers-incentives-to-vc-pe-funds/articleshow/91383159.cms
[84] Sourced from: https://www.bankofbaroda.in/business-banking/msme-banking/loans-and-advances/scheme-for-financing-textile-units

FIGURE 21: 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 Indian textiles and apparel sector, we observe the TH Type II arrangement. TH Type II refers to mechanisms of communication between the actors that 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. The role of the government is primarily to limit cases of market failure. It 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, 2003a, pg.305).

The interactions that need attention are:

- Knowledge exchange between industry actors in order to make them more collaborative rather than competitive which is particularly important in the area of new technology adoption.
- Industry linkages with the knowledgebase in order to generate the requisite skills for the sector. This can be supported through structured placement programmes.
- Joint applied research between industry and the knowledgebase.
- Knowledge exchange and dissemination as well as joint research between knowledge-based institutions, particularly in applied areas.

- KBIs seconding industry experts as faculty to foster practical knowledge exchange.
- Inter-governmental communication and knowledge sharing on the technical applications and uses of textiles.
- Intermediaries better communicate industry needs to knowledge-based institutions.
- Government to better disseminate information on funds amongst industry players, in particular MSMEs.
- Knowledge dissemination between arbitrageurs on the technological aspects of the textiles sector, particularly high-tech application; and
- Increased access of funds for KBIs particularly for the process of ideation to market.

6.3 Barriers to Innovations

This chapter sets out to analyse the results of the ITASSI Survey using 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 Indian textiles and apparel system of innovation. It is crucial to understand which barriers to innovation are significant for the textiles 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 10 (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 11). For the individual actors, barriers to innovation are represented as a frequency analysis.

TABLE 10: 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 11: 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 12) five factors emerge which account for 66.03% of the total variance explained (TVE), namely: '**Industry 4.0**', '**ICT Knowledge and Flows**', '**Knowledge Stocks and Function**', '**Market Function**' and '**Human Capital**'.

Factor 1- '**Industry 4.0**' is the most significant factor barrier to innovation and accounts for 34.18% 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, 'Lack of understanding of I4.0 technologies', 'Cost of I4.0 technologies', 'Lack of access to I4.0 technologies' and 'Lack of infrastructure for I4.0' are deemed to be 'Excellent' (Tabachnick and Fidell, 2007).

The Fourth Industrial Revolution (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, 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 find in a single technology provider, especially in the case of small and micro enterprises (SMEs) (APO, 2019).

The first step towards 4IR implementation is a clear understanding 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).

The textiles sector is undergoing a paradigm shift towards the adoption of I4.0 technologies, some of the reasons being: changing demand and supply dynamics; rising limitations in factors of production; ever evolving technology; and a strong emphasis on sustainability (FICCI, 2020). However, barriers are still faced particularly at the level of MSMEs. Majumdar (2020) articulates that the primary challenges associated with I4.0 adoption by the Indian textile and garments sector are: lack of trained staff; lack of understanding and commitment by senior management; lack of government support; poor research and development; high implementation cost; and fear of failure.

Factor 2 – '**ICT Knowledge and Flows**' underscores that 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). The factor accounts for 10.76% TVE, and the variables loading on the factor are 'ICT capacity', 'Rate of access to ICT' and 'Brain drain' with a Cronbach's Alpha value deemed to be 'Questionable'.

ICT as a technology can improve business practices and increase the efficiency and competitiveness of textile industries. It is the main driver that shifts value along the value chain, enabling new business models, disaggregating production chains and creating new opportunities for textile industries in the global supply chain (Dimelis & Papaioannou, 2011).

The Indian textiles sector is not unfamiliar with the ongoing digital push. The growing acceptance of digital innovations and technologies becoming a part and parcel of the sector is evidenced by the utilisation of digital printing adoption by one of the biggest and most prominent segments of the industry, namely man-made fibre (MMF) (Thomas, 2012). The MMF segment is making extensive use of digital printing technologies such as inkjet and direct-to-fabric printers for the creation of novel designs. However, the overall adoption rate is impeded by barriers such as low digital literacy, financial constraints faced by small- and medium-sized firms in the sector and a lack of genuine interest on the part of policymakers (viz., textiles industry executives) to embrace digital technology (Kanupriya, 2021).

Specific issues faced by the sector include: the vital need to reduce the digital skills gap between the digitally skilled and unskilled through imparting skill-intensive, particularly digital skill-intensive training to existent textiles workers to prevent imminent job losses (Acemoglu & Restrepo, 2018; Autor et al., 2003; Chan et al., 2012). A means to achieve this could be through the textiles sector adopting programmes such as "Digital India" which are especially geared towards achieving this goal. However, a crucial point of importance is that training and educational institutes must shift from imparting only generic training skills to digitally relevant skills so that the employees, both present and future, have the relevant skills in line with the needs of the rapidly evolving digital landscape (Maiti et al., 2020; Pessot et al., 2020). Hence, a proper listing of requirements is needed by every part of the supply chain of the textile industry. In complement to this, there needs to be an adjustment in labour laws with a view to the provision of written contracts and specifying work, wage and social security provisions (Pessot et al., 2020). This would have the impact of formalising the sector leading to better skills retention.

Last but certainly not the least, there is an urgent need to close the digital urban–rural divide and build ICT access through the provision of subsidised access to digital infrastructure. Affordable Wi-Fi and other such vital ICT tools must be made available to textile companies for some time initially so that they gain a footprint in these digital technologies; reducing taxes on ICT goods and services for rural areas; providing network expansion initiatives to ICT operators; and reducing import taxes for local content suppliers (Martinez, 2019; McMillan et al., 2014) are also advised.

Factor 3 - '**Knowledge Stocks and Function**' has a TVE of 0.62% and the associated variables are 'Lack of information (knowledge gap)', 'Lack of technology (technology gap)' and 'Lack of legal framework'. The Cronbach's Alpha value for internal consistency of the factor is 'Acceptable'.

In the case of weaving, most of the infrastructure of the domestic machinery manufacturers is as outdated and obsolete as the machines that they manufacture. This has partly been due to the uncertain demand and lack of incentives for modernisation. High import duties on machinery act as a deterrent for upgrading and modernisation, there is a 27% import duty on textile machinery combined with 18% GST which means an almost 45% additional increase in capex when importing machinery (Dewan, 2022).

Although India has been a leader in the field of software and information technology, this has not translated into weaving. There is a clear need for current technologies to

incorporate more electronics and control hardware and software. More and more machines are incorporating control components such as programmable logic controllers (PLCs) and variable frequency drives. Input systems such as touchscreens help the user control the machine. Such systems are essential for higher productivity and for minimising fabric defects due to yarn breakage or machine malfunctions. Monitoring software can also help better data-collection as well as inventory-management functions (Sanghvi, 2007). To compound this there is an unprecedented demand for trained technicians (machine operators, jobbers, engineers, etc.). However, most students graduating out of engineering colleges and institutes migrate to more lucrative sectors thus leaving the textiles sector with a skills deficit. One avenue to address the challenge of access to technology is the TUFS , which are aimed at modernising the textiles infrastructural base in the country by helping medium- and small-scale enterprises financially (Kanupriya, 2020). However, the limitations are that TUFS are not available for the textile engineering industry which has an impact on the sector.

Factor 4- '**Market Function**' shows the importance of markets in driving innovation through demanding customers and innovative customers, as well as distinct 'rules of the game' articulated through higher resolution regulations. The TVE, amounting to 7.12%, and the variables loading on the factor are 'Lack of demanding customers', 'Lack of innovative customers' and 'Lack of explicit policy support system (government)' with a Cronbach's Alpha categorised as 'Acceptable'.

Market function can be described by rapid changes in technologies, changes in market structure, the instability of market demand, intense fluctuations in the supply of materials, and the probability of market shocks (Nguyen & Harrison 2019; Jansen, Van Den Bosch and Volberda 2006; Sirmon, Hitt and Ireland RD, 2007). Volatility and unpredictability characterise market dynamism (Miller and Friesen, 1983), therefore a high level of market dynamics restricts the ability to distinguish the market boundaries, develop clear successful business models, and identify market participants such as competitors, customers, and suppliers and their respective needs (Eisenhardt and Martin, 2000). Consequently, this leads to external uncertainty thus making it more difficult to predict future market situations, plan and organise their resources, and respond with their own knowledge and related processes. Therefore, firms are continuously required to improve and modify their products and services with innovation to meet customers' needs. Recycling and upcycling are gaining popularity due to market demands and so using newer raw materials, which are technically not virgin materials but upcycled materials, is gaining impetus due to a raised awareness among consumers. Such is the case with a new brand called Golden Feathers that upcycles chicken feathers to create innovative yarn, which has wonderful properties, like being quick drying, and the fabric made out of it looks like Pashmina but is lighter. This brand has also created a high social impact by employing people from tribal communities.

Less dynamic markets, in contrast to highly dynamic markets, present not so frequent changes that market players can usually anticipate or regular changes that occur periodically and are hence predictable. In less dynamic market environments, there is better clarity on market boundaries, the market participants (e.g., firms, customers and suppliers) know each other well and customer demand is relatively stable. Hence, firms do not feel the need to innovate or modify their products or business processes (Eisenhardt and Martin, 2000; Schilke, 2014). The current situation facing the Indian textile market is that of a global slowdown. The Andhra Pradesh Textile Mills Association has announced that around 125-135 mills will stop production due to the unprecedented fall in demand. Slower economic growth, high inflation and energy crises have dented market sentiments across the world (Fibre2Fashion, 2022).

In order to promote innovation, a dynamic market is required. "Regulations which encourage market dynamism, innovation and competitiveness improve economic performance. The aim of regulatory reform is to increase efficiency and effectiveness and to have a better balance in delivering social and economic policies over time" (OECD, 2011 p.4). Poorly designed or weakly applied regulations can hamper business responsiveness, divert resources away from productive investments, hinder entry into markets, reduce job creation and generally discourage entrepreneurship.

Hence, there is the need for administrative simplification (OECD, 2009) with the provision of clear, consistent and coherent rules for dynamic markets to function well. Long-term planning is an important consideration in this process.

Factor 5- How firms can effectively identify, mobilise and deploy '**Human Capital**' 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 4IR.

The TVE, by the factor is 6.35%, and the variables loading on the factor are 'Lack of technically trained manpower' and 'Quality of technically trained manpower' with a 'Good' 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, it is evident that a number of changes in human skills and tasks are 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 interactions, 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). Training of 3D development software, virtual sampling and fitting, online marketing and selling, managing logistics online, etc., are some of the areas where the human resource should be trained to make the innovation process in textiles seamless.

Skills is a general issue observed across the entirety of the Indian textiles sector, except for large companies who can afford to offset the cost of training their employees. The quality of technically trained manpower particularly in the areas of Industry 4.0 and ICT is a challenge. To date, no robust, structured curriculum has been developed that is tailored for the sector. Developing such a curriculum is itself a challenge due to the general lag in technology. Also, there is a lack of access to relevant technology to train individuals on. With respect to specialised courses even institutions like the Textile Sector Skills Council lack this service offering.

The textiles and apparel sector, which is the second largest employer in the country after agriculture, employs approximately 80 million people, with approximately 30 million people directly employed. While the weaving and garments sub sector will continue to hire at a rate of 8–8.5% YOY against the historical growth rate of 9–9.5% to reach 40.7 million in FY 2022, 45–55% of the jobs will require new skill sets (EY, 2017).

A general observation for the textiles sector is that it is not attractive to new graduates. Salaries are not competitive when compared to sectors like ICT, banking, and finance thus there is a dearth of skilled human capital.

Factors 3, 4 and 5 are significant but collectively only account for 21.09% of the TVE. Factors 1 and 2 rank as the most important factors contributing close to 44.94% of the TVE and should be the focus of the system-oriented policies. Once again this expounds the importance of Industry 4.0 technologies as a driver for innovation particularly for the textiles sector. However, it is crucial to note that COVID-19 has had a profound impact on the textiles sector, particularly seeing a greater shift in the adoption of 4IR technologies. It has been the mainstay of industry large firms in the areas of automation and robotics and in the case of MSMEs for predictive maintenance like the use of sensors for monitoring equipment. However, there is still room for improvement as there is a level of hesitation amongst two thirds of manufacturing firms; the reasons being challenges in the field of technical standards, regulatory framework, high investment costs and the lack of skilled personnel (Holtkamp and Anandi Iyer, 2017).

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 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 and how to address barriers and challenges. Policies and their targets should not be unattainable or out of reach and issues need to be addressed from a realistic perspective.

TABLE 12: System-wide barriers to innovation

Barriers to innovation faced by all actors in the textiles sector (N = 1319)									
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	0.857	0.904	34.18%	0.856	2955.022	351	0
		Cost of I4.0 Technologies	0.852						
		Lack of access to I4.0 technologies	0.845						
		Lack of infrastructure for I4.0	0.813						
2	ICT Knowledge and Flows	ICT Capacity	0.75	0.671	10.76%				
		Rate of access to ICT	0.724						
		Brain Drain	0.599						
3	Knowledge Stocks and Function	Lack of information (Knowledge Gap)	0.749	0.7	7.62%				
		Lack of Technology (Technology Gap)	0.733						
		Lack of Legal Framework	0.598						
4	Market Function	Lack of Innovative Customers	0.74	0.627	7.12%				
		Lack of Demanding Customers	0.703						
		Lack of explicit policy support system (government)	0.589						
5	Human Capital	Lack of technically trained manpower	0.877	0.8	6.35%				
		Quality of technically trained manpower	0.849						
Cumulative Total Variance Explained						66.031%			

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[85].

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. Public policy instruments comprise "a set of techniques by which governmental authorities wield their power in 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[86]; ii) Economic and financial instruments (also referred to as market-based instruments)[87]; and iii) Soft instruments (also behavioural instruments)[88] 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.

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

[86] "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 from 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.15,16.

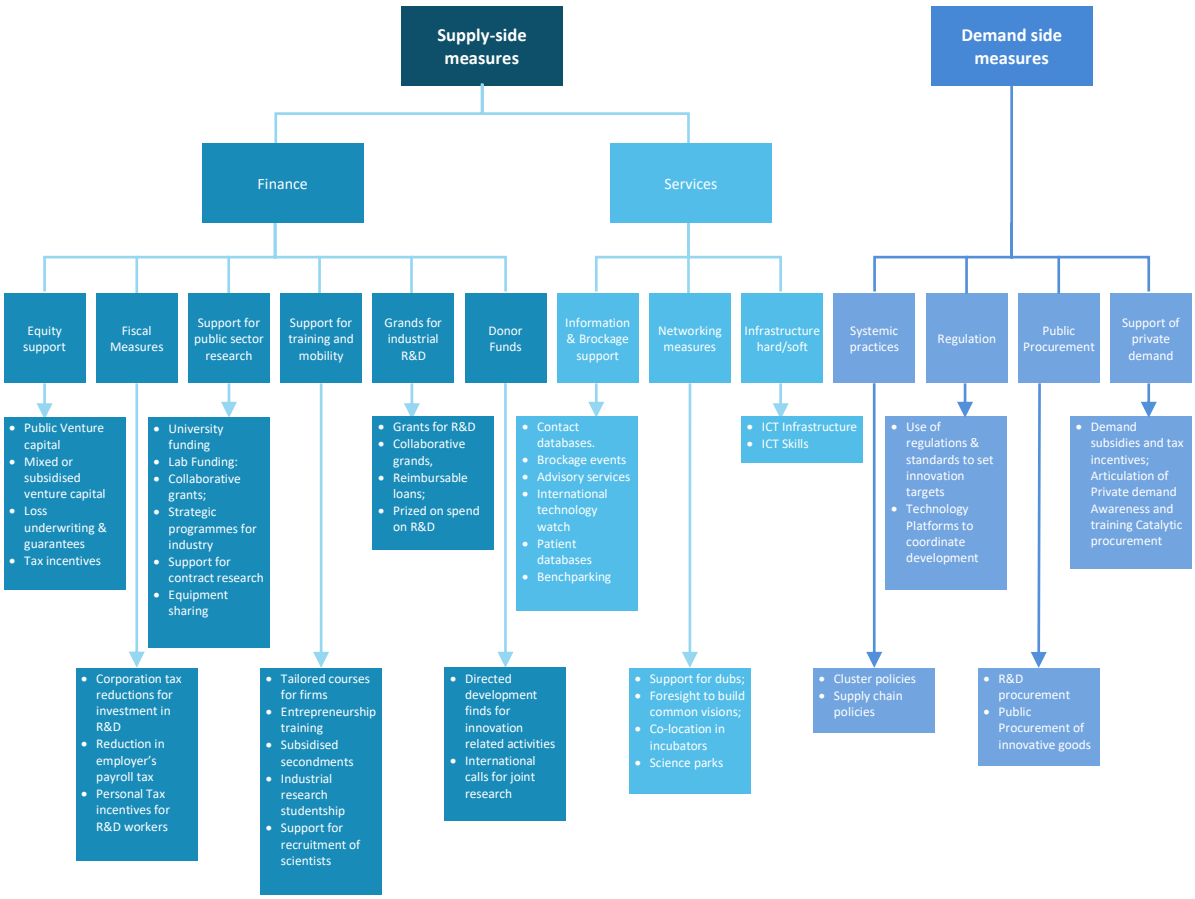
[87] "Economic and financial instruments provide specific pecuniary incentives (or disincentives) and support specific social and economic activities. Generally speaking, they can involve economic means in cash or kind, and they can be based on positive incentives (encouraging, promoting, certain activities) or on disincentives (discouraging, restraining, certain activities)" Borras and Edquist, 2013., pg.15,16.

[88] Ibid.

An alternative way to classify innovation policy is in terms of supply-side measures and demand-side measures (see Figure 22). 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).

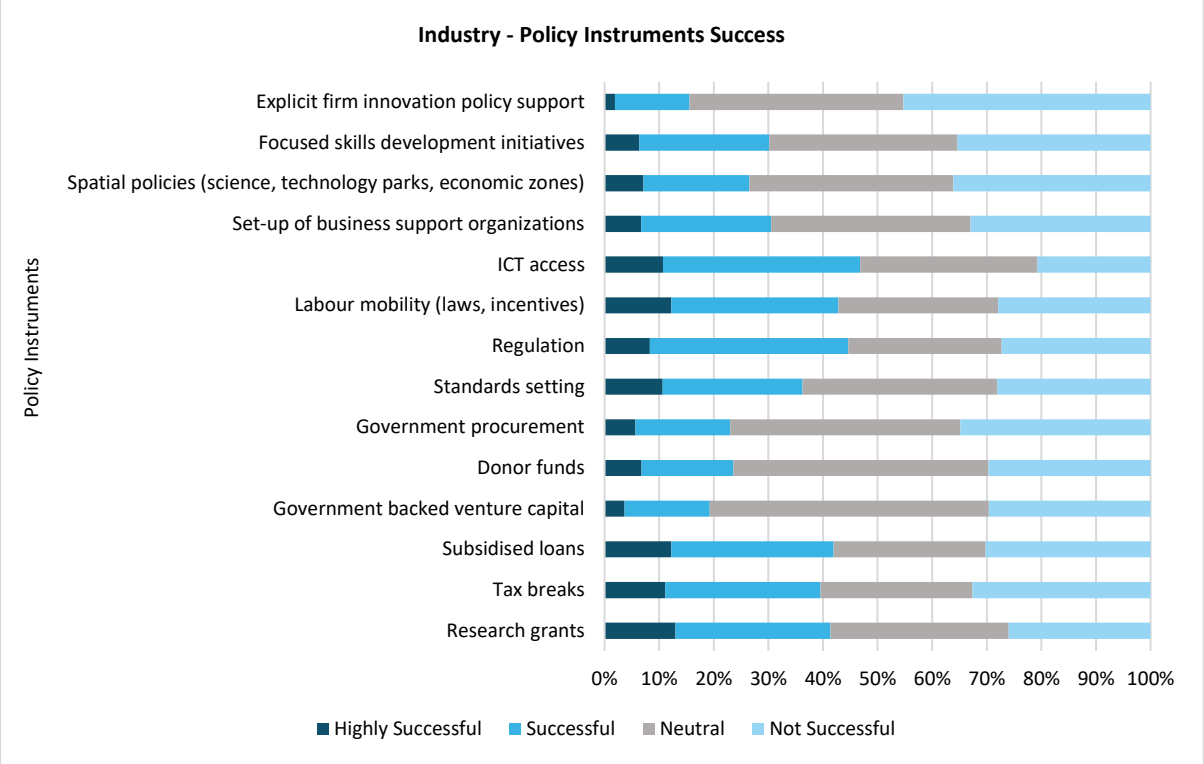
Using this classification to order policy instruments of the Indian manufacturing sector, the following groupings emerge: i) Supply-side finance policies include – research grants, subsidised loans, government-backed venture capital, donor funds; ii) Supply-side services include – ICT access and focused skills development initiatives; iii) Demand-side measures include – tax breaks, spatial policies, government procurement, standard 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.

FIGURE 22: Policy taxonomy



6.4.1 Industry

FIGURE 23: Success of policy instruments – Industry



From the perspective of industry respondents (see Figure 23 above), supply-side service, namely, 'ICT access' is deemed to be the most successful as reported by 47% of survey respondents out of which 11% consider it 'Highly Successful' and 36% consider it 'Successful'. On the other hand, 41% of respondents reported 'Explicit firm innovation policy support' as unsuccessful while a similar percentage of respondents (42%) chose to remain 'Neutral'. This is followed by the 'Spatial policies' instrument which has been reported as unsuccessful by 36% of industry respondents with the same percentage of respondents choosing to remain 'Neutral'.

The importance of ICT access is recognised by the "National Policy on Information Technology 2012" as it highlights the need "to enable long-term partnerships 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. facilitate growth of IT SMEs and use of IT across all SMEs" (MEITY, 2012:7). The policy outlines the need to intervene and "promote the 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). 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.

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 can be achieved through spatial policy instruments such as special economic zones (SEZs), cluster development as well as industrial and technology parks. For example, the "Comprehensive Powerloom Cluster Development Scheme" (CPCDS) was introduced in 2008 for developing Erode (Tamil Nadu) as a powerloom mega cluster to create world-class infrastructure to integrate the production chain, to fulfil the business needs of the local small and medium enterprises (SMEs) and to boost production and export, etc. An independent evaluation of the scheme revealed that projects were not progressing as planned and the constraints faced in implementing the project were also identified. Consequently, the CPCDS was modified to include Bhilwara (Rajasthan) and Ichalkaranji (Maharashtra) as powerloom mega clusters respectively (Ministry of Textiles, 2013).

The "Scheme for Integrated Textile Parks" (SITP) was another scheme that was launched in 2005 to create new textile parks with international standards at potential growth centres, but due to its slow progress, it was later modified to attain objectives set up under the scheme. This year, the GoI has proposed the "Mega Investment Textiles Parks 2022" (MITRA) to create world-class infrastructure with plug and play facilities to create global export champions. But the success of these schemes will depend upon effective implementation and adequate provisioning.

6.4.2 Knowledge-Based Institutions

FIGURE 24: Success of policy instruments - Knowledge-based institution

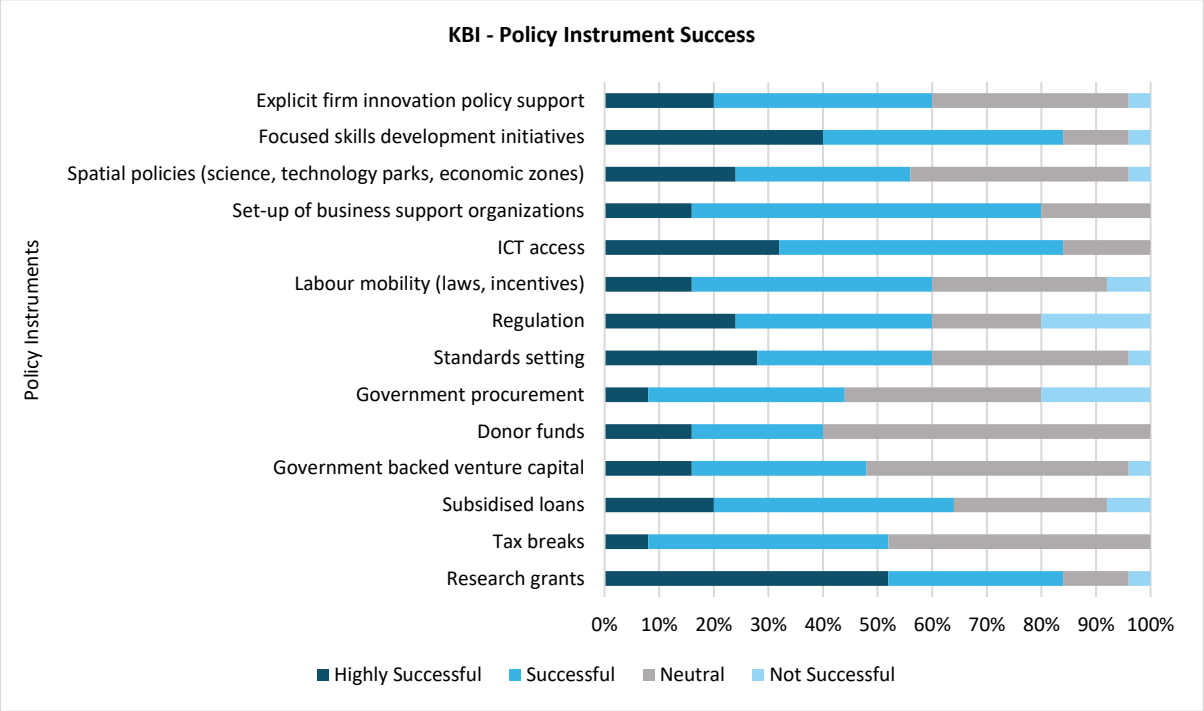


Figure 24 shows that the majority of knowledge-based institution respondents have reported most policy instruments as successful. It is also evident that the supply-side finance measure of 'Research grants' is deemed to be the most successful as reported by 84% of respondents out of which 52% of respondents noted it as 'Highly Successful' while the remaining 32% claimed it to be 'Successful'. Similar response patterns have been noted for supply-side services, namely 'Focused skill development initiatives' and 'ICT access'. Contrary to the view of industry respondents, 'Focused skill development initiatives' has been reported successful by 84% of KBI respondents with 40 and 44% of respondents calling it 'Highly Successful' and 'Successful' respectively. 'ICT access' has been reported successful by 84% of respondents (with 32% reporting it as 'Highly Successful' and 52% reporting it as 'Successful'). Another supply-side finance measure that has been reported to be successful is 'Subsidised loans' at 64% ('Highly Successful' and 'Successful' responses combined).

The success of 'Research grants' as a policy instrument can be attributed to the funds received through nationwide initiatives like the "National Technical Textiles Mission" (NTTM). The NTTM was launched in March 2020 with the intention to position India as a global leader in technical textiles. It aims to promote R&D of specialty fibres from carbon, Nylon-66, glass, aramid and other high technology polymers; increase the application of geotextiles, agrotextiles, medical textiles, protective textiles and other segments of technical textiles in various application areas. Both basic research activities and application-based research is conducted by scientific/industrial/academic laboratories of repute, as approved by the Mission Steering Group.

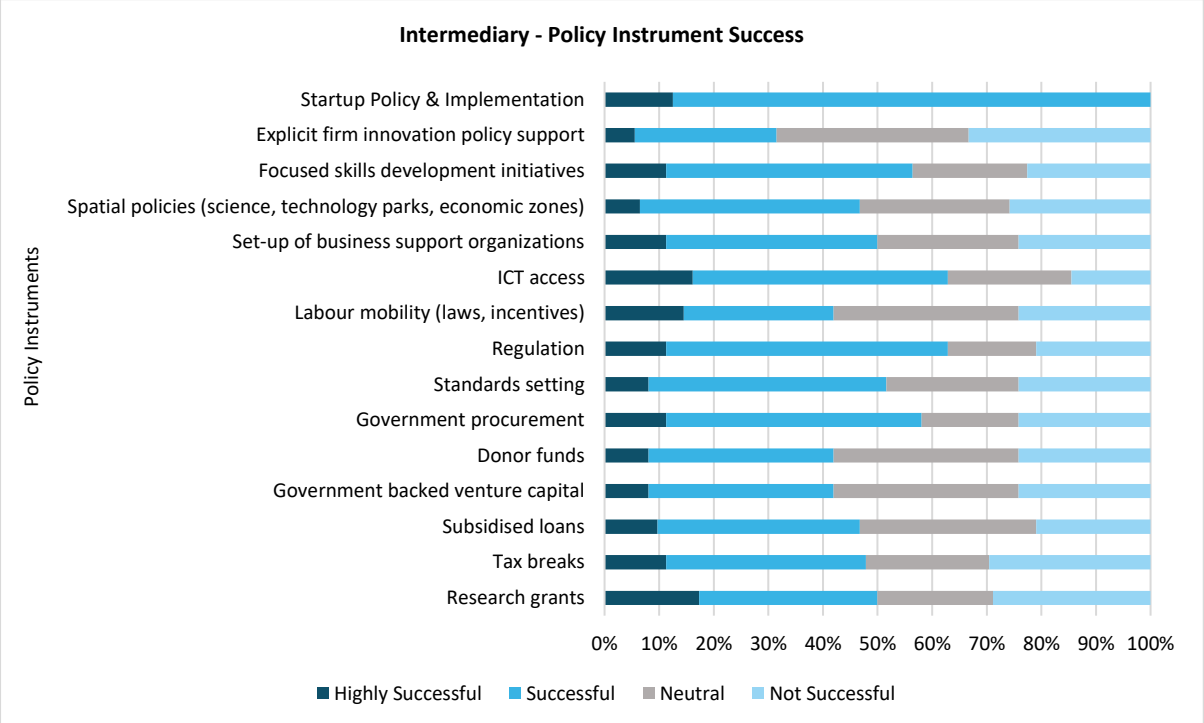
In order to address the shortage of skilled labourers in all segments of the textile value chain, the Ministry of Textiles has undertaken several focused skill development initiatives under schemes such as the "SAMARTH (Scheme for Capacity Building in Textile Sector)", and the "Scheme for Development of Knitting and Knitwear Sector" under "PowerTex India 2019", etc. In 2013, the National Skill Development Corporation (NSDC) approved the Textile Sector Skill Council (TSSC) for the development of skills in the spinning, weaving, processing and handloom sectors of the textile industry. Furthermore, to fulfill the specific reskilling and upskilling needs of artisans and weavers in India, the Ministry of Skill Development and

Entrepreneurship (MSDE) announced special pilot projects such as "Recognition of Prior Learning" (RPL). RPL is a skill certification component to enable Indian youth to take up industry-relevant skill certification which will help them to secure a better livelihood.[89] The government has been running upskilling projects under RPL to improve the competencies of the unorganised workforce of the handicraft industry. Efforts have also been made to align artisans and weavers with the standardised National Skills Qualifications Framework.[90]

On the other hand, 'Regulation' and 'Government procurement' emerge as the most unsuccessful policy instruments with 20% of respondents each reporting them as 'Not Successful'. 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). There is a lack of a comprehensive central legislation solely governing public procurement in India. Rather, 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 GoI 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 format, 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. The government has also been making efforts to ensure transparency and fairness in the public procurement system. In 2012, the GoI enacted the "Public Procurement Bill". 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). The 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." The present government is yet to introduce the bill.

6.4.3 Intermediary

FIGURE 25: Success of policy instruments – Intermediary



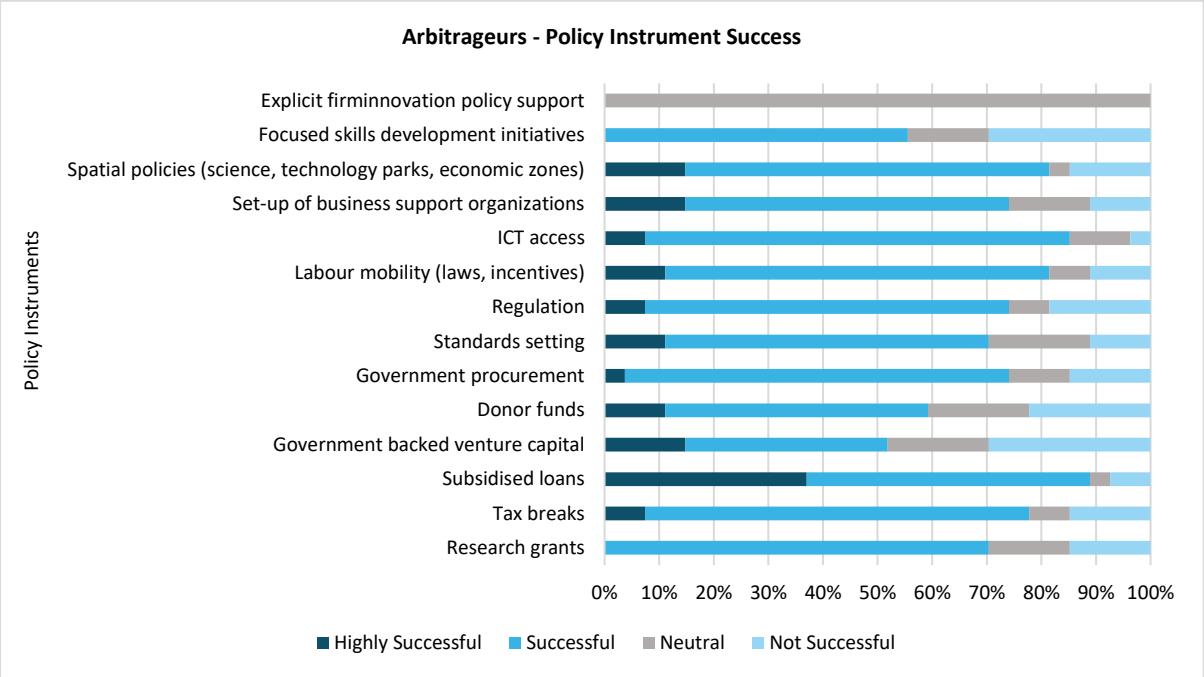
[89] Sourced from: https://www.pmkvyofficial.org/components-of-the-scheme
[90] Sourced from: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1812163

From Figure 25, it can be seen that 'ICT access' and 'Regulation' emerge as the most successful policy instruments as reported by 63% of respondents each ('Highly Successful' and 'Successful' policy responses combined). This is closely followed by 'Research grants' and 'Government procurement' at 58% each. On the other hand, 'Explicit firm innovation policy support' emerges as the most unsuccessful policy instrument. This points to a lack of instruments that target firm level innovation and that focus on the firm as the prominent target group. The demand-side measure 'Spatial policies' emerges as the second most unsuccessful policy instrument reported by 26% of respondents. This mirrors the view of industry respondents and has been explained in the previous section.

It is true that regulations can both enhance and constrain a business activity. Improvements in firm entry regulation are associated with higher productivity (GII 2020) and labour regulations can determine the firms' unit labour costs (Amirapu and Gechter 2019). The NITI Aayog Innovation Index 2021 underscores this by articulating that "governments that enact and enforce open and fair procedures, regulate markets efficiently, protect property rights, and lower the burden of regulations are more likely to see higher levels of innovative entrepreneurial activity". The success of 'ICT access' and 'Research grants' is reflected and explained in the sections above. However, it is interesting to note that the majority of intermediaries consider 'Government procurement' as successful, which conflicts with the viewpoint of industry and KBIs in the previous sections.

6.4.4 Arbitrageurs

FIGURE 26: Success of policy instruments – Arbitrageurs



It is evident from Figure 26 above that all policy instruments have been reported as successful except for 'Explicit firm innovation policy support', 'Focused skill development initiatives' and 'Government-backed venture capital'. In the case of 'Explicit firm innovation policy support' all the respondents are 'Neutral' while for the other two policy instruments 30% of each respondents report them as unsuccessful. As discussed in the KBI section above, the government has launched initiatives focused on the development of skilled human capital in the sector, but emerging technologies and rapid automation accompanied by a rising demand for skilled workers have put a premium on training which in turn is associated ironically with a tight labour market, better working conditions and higher than minimum wages for a subset of the workers in this labour-intensive sector. There is a need to calibrate skill requirements in alignment with Industry 4.0 technologies that are drastically changing the nature of work.

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.91 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 recognised that the absence of venture capital investment thwarts innovation in India (NITI Aayog 2021).

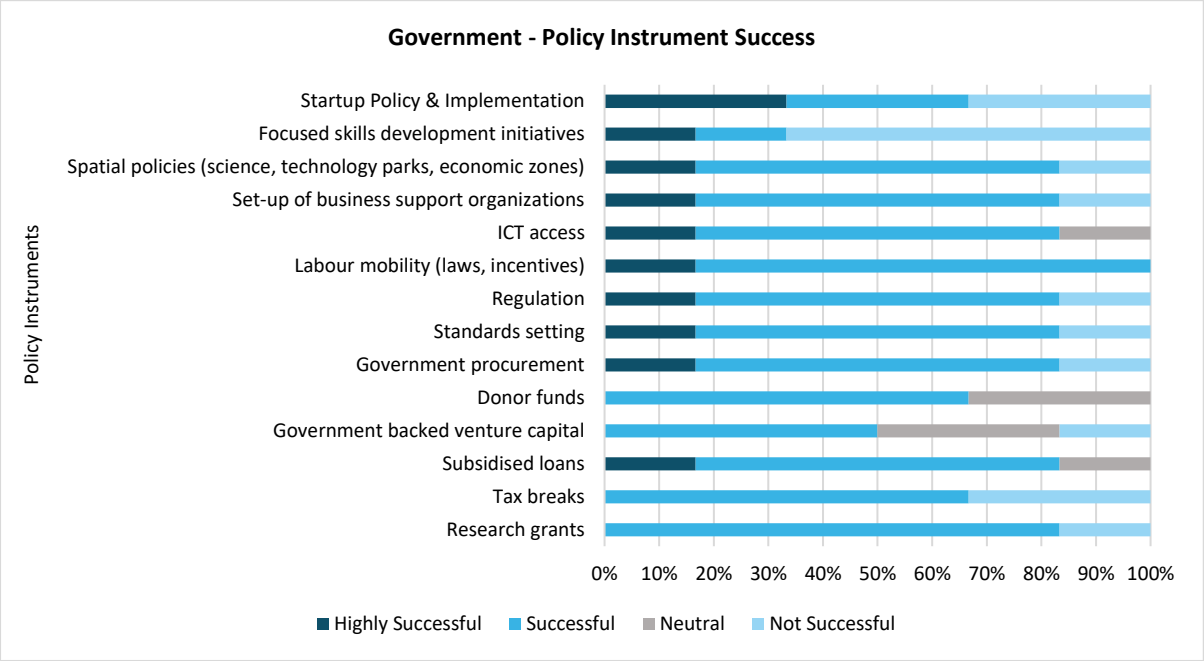
In terms of policy instrument success, the supply-side finance instrument of 'Subsidised loans' emerges as a clear winner with 52% of respondents reporting it as 'Highly Successful' and 37% as 'Successful'. This is followed by the supply-side service instrument 'ICT access' at 85% (7% saying 'Highly Successful' and 78% saying 'Successful'). 'ICT access' has also been reported as successful by all the actors before this and has been explained in the sections above. Other successful instruments reported by arbitrageurs include 'Spatial policies' (81%), 'Labour mobility (81%), 'Tax breaks' (78%), 'Set-up of business support organizations' (74%), 'Regulation' (74%) and 'Government procurement' (74%). This viewpoint on demand-side measures namely, 'Regulation' and 'Government procurement' is divergent from the viewpoint of the industry and KBIs but matches that of intermediaries.

The success of 'Subsidised loans' as a supply-side finance policy instrument is convergent with the fact that the Indian textiles and apparels industry has historically been dependent upon financial assistance from the government in the form of subsidies and grants. Several fiscal incentives have been introduced by the government to provide financial assistance to facilitate technology upgradation such as the "Yarn Bank Scheme, Credit Linked Capital Subsidy Scheme for Technology Upgradation" (CLCSS) and "Pradhan Mantri Credit Scheme, Common Facility Centre Scheme" (CFC), etc. Furthermore, the government has approved an extension of the "Rebate of State and Central Taxes and Levies Scheme" (RoSCTL) for apparel and made-ups for three years along with an announcement of the "Remission of Duties and Taxes on Exported Products" (RoDTEP) rates for the other textile segments (PIB, 2021).

The Indian textiles and apparels sector is heavily reliant on labour-intensive manufacturing methods and migrant labourers. The labour migration patterns are fluid and the labour contractors favour a fragmented labour force as it comes with a minimal risk of unionisation (Dalme, 2019). This raises questions on the exploitation of labourers and limits the ability of the sector to achieve economies of scale and become globally competitive.

6.4.5 Government

FIGURE 27: Success of policy instruments – Government

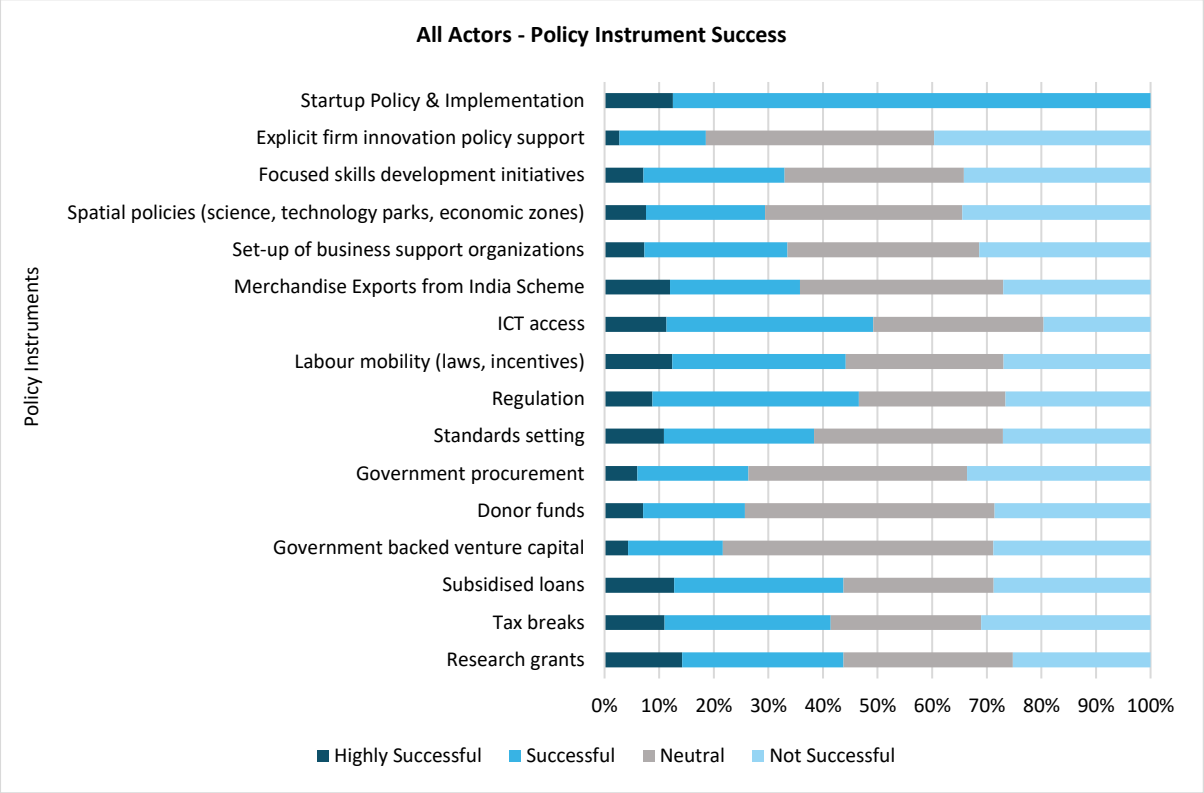


[91] Government-backed venture capital funds include: SBI Capital Markets Ltd. (SBICAP), Canbank Venture Capital Fund Ltd. (CVCFL), IFCI Venture Capital Funds Ltd. (IFCI Venture), and SIDBI Venture Capital Limited (SVCL). Available at: https://www.indianweb2.com/2015/01/13-govt-venture-capital-firms-for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

The last actor perspective on the relative success of policy instruments is that of the Indian government (Figure 27 above). It is evident that all policy instruments have been reported as successful by government respondents except for 'Focused skill development initiatives' that has been reported as unsuccessful by 67% of respondents. This calls for the government to reflect on the orientation, relevance and quality of skills development taking place in the country. Moreover, all the respondents reported 'Labour mobility (laws, incentives)' as 'Successful', which mirrors the viewpoint of arbitrageurs in the previous section.

6.4.6 All Actors

FIGURE 28: Success of policy instruments - All actors



Summarising the above results, the most successful policy instrument reported by all actors in the textiles and apparels sector is 'ICT access' (49%), and the most unsuccessful policy instrument is 'Explicit firm innovation policy support' (36%). This is reflective of the barriers reported under market function with respect to 'Lack of explicit policy support system (government)' (see Table 12: System-wide barriers to innovation). At the same time, about 30-35% of respondents took a neutral stand in the case of all policy instruments in this sector.

7.

Recommendations

Recommendations

Literature on innovation policy draws attention to the complex and heterogeneous nature of available policy instruments. 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 textiles and apparel 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 target 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 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 13 below highlights the short-, medium- and long-term recommendations based on the analysis conducted.

TABLE 13: 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 ITASSI. Robustness and credibility of data shared at the system level.	Need to integrate and standardise national actor databases with respect to the ITASSI. • 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 Start-up 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 ITASSI Survey within a national institution with top-down mandate. • Make the ITASSI 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 level (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 - ISIs, • 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 actors 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 ITSSI	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). • Promotion in 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, start-up kits).
Industry modes of interaction that require attention: **Intra:** Despite user-producer relationship between IND actors there are few linkages in terms of tacit knowledge transfer & joint research activities. **Inter:** **IND - GOV** Poor public financing for the textile sector and few licensing agreements. **IND - KBI** Minimal joint research activities and low innovation outputs. **IND-INTER** Few linkages in form of trademarking & joint research **IND-ARB** Few linkages in terms of formal meetings, informal meetings & seminar/trainings	Lack of knowledge exchange between industry actors. Need to make them more collaborative rather than competitive which is particularly important in areas of new technology adoption. Low innovation activity in the textile 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.	**Intra** • Specific policy interventions to create robust supplier development ecosystem. (i.e., technology-based linkages between large companies & MSME's) • Creation of knowledge exchange platforms in the form of annual buyer-supplier summits stressing on outsourcing strategies, sustainability, new market opportunities, etc. **IND-GOV** • Incentivizing MSME's for adopting Textile 4.0 technologies. (Process automation, cognitive manufacturing, market intelligence, green factory). • Reduce procedural bottlenecks for availing finance at macro, meso & micro level (simplified compliance structure). • Leverage energy efficient technologies in MSMEs through policy actions. **IND-KBI** • Increase cross-functional knowledge/research by collaborating with electronics/IT departments for smart textiles. • Promote intensive knowledge-based programs on international quality standards & compliance. • Promote intensive knowledge-based programs on international quality standards & compliance. **IND-ARB** • Assist MSME's by providing training on currency risk management.
Knowledge-based institutions modes of interaction that require attention: **Intra:** Few linkages in the form of joint research activities, secondments & co-publishing and joint patents. **Inter:** **KBI-IND** Low tacit knowledge transfer, recipient of funding and joint ventures. **KBI-INT**	KBIs working in silos Limits commercial adoption and application of new technology. Limits KBI awareness of industry needs. Challenges in knowledge dissemination & lack of access to funds for KBIs particularly for the process of ideation to market.	**Intra** • Create forums where KBIs come together on a regular basis. • Create formal forums for joint research, meetings, seminars and training with respect to textile sector. • Encourage international research-oriented collaboration & link to current accreditation system. • Align local KBIs with central R&D institutes. • Promote faculty exchange programs with leading global universities. **KBI-IND** • Institutionalize R&D funds to increase academia-industry collaboration. • Rigorous joint training & up skilling programs. • Establish Design Centers/Studios to foster innovation in fashion industry.

Few joint research activities & minimal innovation outputs. **KBI-ARB** Few seminars/training activities and joint research activities.		• Encourage joint initiative to establish incubation centers in every NIFTs/NIDs/IICT/IIHT. • Facilitating publishing of industrial research from point of view of IPR and other legalities. • Involving industry in content and design of curriculum • Seconding industry experts as faculty to foster practical knowledge exchange. **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** • Promote sponsored training programs & offer scholarships/stipend to students for research.
Intermediary modes of interaction that require attention: **Intra:** Limited joint research and co-publishing activities. **Inter:** **INT-IND** Few joint research activities, user-producer relationships & less conversion of innovation inputs to outputs. **INT-KBI** Few linkages as secondments and joint research activities	Lack of codification of knowledge with industry. Gap in communication of industry needs to knowledge-based institutions.	**Intra** • Incentivize for conducting global market-specific studies to leverage diversification of products in exports. • Enable research in packaging technology to improve export competitiveness. • Focus on circular business model & practices, use of alternate materials, cost-effective recycling technologies. **INT-IND** • Take into consideration the value addition of stakeholders in the formulation of new projects/activities (not as a second thought but from the onset). • All avenues of dissemination of information and knowledge must be leveraged, in line with the target audience. • Leveraging the CSR funds of industry to address topics related to circular economy **INT - KBI** • Integrate all Centre of Excellence (CoE's) with KBIs. • Initiate joint cluster development programs in technical textiles.
Arbitrageurs' modes of interaction that require attention: Low reporting of linkages by ARB **Intra:** Few interactions through recipient of funding **Inter:** Overall, there are few linkages with other actors. **ARB-KBI** Few joint research activities **ARB-INTER** Less recipient of funding		Have regular fora addressing the areas of future technology trends skills and with inclusion of other system actors **Intra** • Robust credit & insurance system for export houses. • Bringing public & private sources of finance together to leverage the R&D spending. **ARB-KBI** • Representation of Venture Capitalists/Angel Investors on Board of Studies. • Scale-up & replicate Innovation Voucher Programme across the country. • Scaling up of programmes like "Startup Investopreneur" by IIM Lucknow Incubator for training new investors on early-stage investments. **ARB-INTER** • Facilitation of funds to upgrade the testing facilities in technical textiles across the country.

Latent barriers - All Actors • Industry 4.0 (Lack of understanding of I4.0 technologies, Cost of I4.0 Technologies, Lack of access to I4.0 technologies, Lack of infrastructure for I4.0) • ICT & Knowledge Flows (ICT Capacity, Rate of access to ICT, Brain Drain) • Knowledge Stocks & Function (Lack of information, Knowledge Gap, Lack of Technology (Technology Gap); Lack of Legal Framework) • Market Function (Lack of Innovative Customers, Lack of Demanding Customers, Lack of explicit policy support system (government)) • Human Capital (Lack of technically trained manpower, Quality of technically trained manpower)		**Industry 4.0** • Enabling pilot projects providing world class manufacturing facilities for sub-sectors like handicrafts, weaving & processing. **ICT & Knowledge Flows** • Scout - Standardize - Transmit data on existing technologies. • Wider education at MSME level for digital literacy. **Knowledge Stocks & Function** • Like TUFS Scheme, certain financial pool for digitalization of MSMEs should be created (ERP software). • Digitalization in entire supply chain (custom clearances/shipping bills) **Market Function** • Integration of Textile Supply & User Industry under Ministry of Textiles. **Human Capital** • Imparting digital intensive skill training to existing textile workers. • Adopting sector-specific National Manufacturing Competitiveness Programme. • Strengthening of Textile Sectorial Innovation Council (TSInC) & develop a sectorial roadmap for innovation.
Unsuccessful policy instruments from the perspective of Industry: • Explicit firm innovation policy support • Focused Skills Development Initiatives • Spatial Policies	Strengthen and focus delivery of policy to address specific gaps	• Bringing Textile Engineering Industry under TUFS Scheme which will reduce importing of high-end technologies & create competition. • Leverage Export Incentives with lower rate of interest. • Recalibrating & scaling up of training programs under Textile Sector Skill Council in collaboration with Industry.
Unsuccessful policy instruments from the perspective of KBI: • Regulation • Government Procurement • Subsidized Loans	Strengthen and focus delivery of policy to address specific gaps	• Need of legislative actions for increasing use of technical textiles in public infrastructure development. • Encourage states to institute separate ministry/department for textiles & apparels. • Enable periodic quality checks in procurement process (pre & after purchase). • Sustainable Public Procurement (use of recycled materials). • Conduct research studies on incentive structure of global competing countries.
Unsuccessful policy instruments from the perspective of Intermediary: • Explicit firm innovation policy support • Spatial Policies • Donor Funds	Strengthen and focus delivery of policy to address specific gaps	• Set a framework (KPIs) to assess National Technical Textiles Mission (NTTM) • Ancillary services should be inducted in Infrastructure-related spatial policies. • Increase funding support towards technical research associations (TRAs). • Like Skill Strengthening for Industrial Value Enhancement (STRIVE) Project, uptake similar initiatives with donor funding agencies.
Unsuccessful policy instruments from the perspective of Arbitrageurs: • Focused skill development initiatives • Govt. backed venture capital • Donor Funds	Strengthen and focus delivery of policy to address specific gaps	• Setting-up of sector-specific venture capital fund for supporting startups. • Need to channelize CSR funds on research & development rather than training. • Focused efforts for Sustainable (ESG) Finance to promote circular economy.

8.

References

References

Acemoglu, D., and Restrepo, P. (2018) The race between man and machine: Implications of technology for growth, factor shares, and employment. American Economic Review, 108 (6), pp. 1488–1542.

Adams, P., Freitas, I.M.B., and Fontana, R. (2019) Strategic orientation, innovation performance and the moderating influence of marketing management. Journal of Business Research, 97, pp.129-140.

AEPC (2021) Annual Report - Indian Textile and apparel industry. Available from: https://aepcindia.com/system/files/Annual%20T%20and%20A%20Industry%20Report-2021.pdf [Accessed 22nd October 2022].

Alcacer, V., and Cruz-Machado, V. (2019) Scanning the Industry 4.0: a Literature Review on Technologies for Manufacturing Systems. Engineering Science and Technology, 22, pp. 899-919, DOI: 10.1016/j.jestch.2019.01.006 [Accessed 22nd October 2022].

Allen, J., James, A. D., and Gamlen, P. (2007) Formal versus informal knowledge networks in R&D: a case study using social network analysis. R&D Management, 37 (3), pp. 179-196.

All India Artisans and Craft workers Welfare Association (AIACA) (2017) National Handicrafts Policy Report. Available from: https://www.aiacaonline.org/wp-content/uploads/2018/06/National-Handicrafts-Policy-Report_Full-version_Final.pdf [Accessed 22nd October 2022].

Anheier, H.K. (2004) The third sector in Europe: Five theses (pp. 285-299). Springer US

Anum, A., and Thakore, D.V. (2011) An analytical study of the Functioning and Problems of the Power Loom Industry in Maharashtra with special reference to Malegaon District, Nashik. International Journal of Trade, Economics and Finance, 2 (3), pp. 194-199, DOI: 10.7763/IJTEF.2011.V2.102 [Accessed 22nd October 2022].

Arza, V. (2010) Channels, benefits and risks of public–private interactions for knowledge transfer: Conceptual framework inspired by Latin America. Science and Public Policy, 37 (7), pp. 473–484. Available from: https://doi.org/10.3152/030234210X511990 [Accessed 22nd October 2022].

Asian Development Bank (2014) Indonesia Needs Knowledge Driven Economy To Sustain Growth – Report. Available from: https://www.adb.org/news/indonesia-needs-knowledge-driven-economy-sustain-growth-report [Accessed 22nd October 2022]

Asian Productivity Organisation (2019) Gearing Up to Industry 4.0 Digitization Strategies for SMEs. Available from: https://www.apo-tokyo.org/publications/wp-content/uploads/sites/5/Gearing-Up-To-Industry-4.0-Digitization-Strategies-for-SMEs.pdf [Accessed 28th August 2022]

Assimakopoulos, D., and Yan, J. (2006) Sources of knowledge acquisition for Chinese software engineers. R&D Management, 36 (1), pp. 97-106.

Autor, D. H., Levy, F., and Murnane, R. J. (2003) The skill content of recent technological change: An empirical exploration. Quarterly Journal of Economics, 118 (4), pp. 1279–1333.

Bai, C., Dallasega, P., Orzes, G., and Sarkis, J. (2020) Industry 4.0 technologies assessment: A sustainability perspective. International journal of production economics, 229, pp. 107776.

Bain & Company (2022) India Venture Capital Report 2022. Available from: https://www.bain.com/insights/india-venture-capital-report-2022/ [Accessed 16th January 2023]

Bank of Baroda (n.d) Schemes for financing Textile Units. Available from: https://www.bankofbaroda.in/business-banking/msme-banking/loans-and-advances/scheme-for-financing-textile-units [Accessed 22nd October 2022]

Bank of Baroda (2022) Banking Beyond Tomorrow – Annual Banking Conference 2022. Available from: https://www.bankofbaroda.in/hi-in/-/media/project/bob/countrywebsites/india/content/media/press-releases/banking-beyond-tomorrow-annual-banking-conference-2022-22-07-2022-26-10.pdf [Accessed 22nd October 2022]

Bartels, F.L. Voss, H. Lederer, S., and Bachtrog, C. (2012) Determinants of National Innovation Systems: Policy Implications for developing countries. Innovation, 14 (1), pp. 2–18. Available from: https://doi.org/10.5172/impp.2012.14.1.2 [Accessed 22nd October 2022]

Basant, R., and Fikkert, B. (1996) The effects of R&D, foreign technology purchase, and domestic and international spillovers on productivity in Indian firms. Review of Economics and Statistics, 78 (2), pp. 187–199. Available from: https://doi.org/10.2307/2109920 [Accessed 22nd October 2022]

Basant, R. (1997) Technology strategies of large enterprises in Indian industry: Some explorations. World Development, 25 (10), pp. 1683–1700. Available from: https://doi.org/10.1016/S0305-750X(97)00057-0 [Accessed 22nd October 2022]

Baskaran, A., and Muchie, M. (2010) Towards a unified conception of innovation systems, IERI Working Paper 2010 0002, Institute for Economic Research on Innovation. Available from: https://eprints.mdx.ac.uk/4470/1/BaskaranMammo_Working_Paper_on_Towards_Unified_Conception_of_Innovation_Systems.pdf [Accessed 16th January 2023]

Baumgartner, H., and Steenkamp, J-B. E. M. (2001) Response styles in marketing research: A cross-national investigation. Journal of Marketing Research, 38, pp. 143-156.

Baygan, G., and Freudenberg, M. (2000) The internationalization of venture capital activity in OECD countries: Implications for

measurement and policy. OECD Science, Technology and industry Working Papers No. 2000/7, Paris, OECD.

Bekkers, R., and Freitas, I.M.B. (2008) Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter? Research policy, 37 (10), pp.1837-1853.

Bergek, A., Hekkert, M. P., and Jacobsson, S. (2008) Functions in Innovation Systems: A framework for analysing energy system dynamics and identifying goals for system building activities by entrepreneurs and policy makers. In: Foxon, T., Kohler, J., and Oughton, C. (eds.) Innovations for a low carbon economy: Economic, institutional and management approaches. Edward Elgar Publishing.

Bergek, A., Jacobsson, S., Hekkert, M. and Smith, K. (2010) Functionality of innovation systems as a rationale for and guide to innovation policy. In The theory and practice of innovation policy. Edward Elgar Publishing.

Bhaduri, S., and Ray, A.S. (2004) Exporting through technological capability: Econometric evidence from India's pharmaceutical and electrical/electronics firms. Oxford development Studies, 32 (1), pp. 87-100.

Bhagavan, M. R. (1985) Capital goods sector in India: Past and present trends and future prospects. Economic and Political Weekly, pp. 404–421.

Bhattacharjya, D., Khasru, A., Bhuimali, A., and Saha, S. (2020) Status, potentials, constraints and strategies for development of sericulture farming system in West Bengal state of India (review). Bulgarian Journal of Agricultural Science. 26. pp. 709-718.

Bhavdiep, K. (2020) Industry 4.0 for Textile & Fashion. Available from: https://www.linkedin.com/pulse/industry-40-textile-fashion-bhavdiep-k- [Accessed 16th October 2022]

Binz, C., Gosens, J., Yap, X.S., and Yu, Z. (2020) Catch-up dynamics in early industry lifecycle stages—a typology and comparative case studies in four clean-tech industries. Industrial and Corporate Change, 29 (5), pp. 1257-1275.

Boer, E., George, K., and Giraud, Y. (2021) CEO dialogue: Perspectives on reimagining operations for growth. McKinsey. 7 April. Available from: https://www.mckinsey.com/business-functions/operations/our-insights/ceo-dialogue-perspectives-on-reimagining-operations-for-growth [Accessed 28th August 2021].

Bonekamp, L., and Sure, M. (2015). Consequences of Industry 4.0 on Human Labour and Work Organisation. J. Bus. Media Psychol., 6, pp. 33–40.

Breschi, S., and Malerba, F. (1997) Sectoral innovation systems: technological regimes, Schumpeterian dynamics, and spatial boundaries. Systems of innovation: Technologies, institutions and organizations, 1, pp. 130-156.

PTI (2018) The future is 3D: India witnesses spurt in additive manufacturing. Business Standard. 8th August 2018. Available from: https://www.business-standard.com/article/companies/the-future-is-3d-india-witnesses-spurt-in-additive-manufacturing-118080801301_1.html [Accessed 22nd October 2022]

PTI (2022) Union Cabinet approves Rs. 10,683-crore PLI scheme for textile sector. Business Standard. 9th September 2021. Available from: https://www.business-standard.com/article/economy-policy/union-cabinet-approves-rs-10-683-crore-pli-scheme-for-textile-sector-121090801448_1.html [Accessed 22nd October 2022]

Cabinet Committee on Economic Affairs (2020) Cabinet approves Extension of Norms for Mandatory Packaging in Jute Materials. Available from: https://pib.gov.in/PressReleasePage.aspx?PRID=1668402 [Accessed 8th August 2022].

Cai, Y., and Amaral, M. (2021) The Triple Helix Model and the Future of Innovation: A Reflection on the Triple Helix Research Agenda, Triple Helix, 8 (2), 217-229. Available from: https://doi.org/10.1163/21971927- 12340004. [Accessed 22nd October 2021].

Carlsson, B., and Stankiewicz, R. (19910 On the nature, function and composition of technological systems. Journal of evolutionary economics, 1 (2), pp.93-118. Available from: https://doi.org/10.1007/BF01224915 [Accessed 22nd October 2021].

Carlsson, B. (2016) Industrial dynamics: A review of the literature 1990–2009. Industry and innovation, 23 (1), pp.1-61.

Central Pollution Control Board (2022) Categorization of Industrial Sectors. Available from: https://cpcb.nic.in/categorization-of-industrial-sectors/ [Accessed 22nd October 2022]

Central Silk Board (n.d). Central Sector Scheme 2012 – 2017 Available from: https://csb.gov.in/wp-content/uploads/2018/04/Implementation-Guidelines.pdf [Accessed 8th August 2022].

Central Silk Board (n.d) R&D, Training, Transfer of Technology & IT Initiatives 2012 – 2017. Available from: https://csb.gov.in/wp-content/uploads/2018/04/RD-Training-TOT-IT-Initiative.pdf [Accessed 7th August 2022]

Chaminade, C., Lundvall, B.Å., and Haneef, S. (2018) Advanced introduction to national innovation systems. Edward Elgar Publishing.

Chan, M., Esteve, D., Fourniols, J. Y., Escriba, C., and Campo, E. (2012). Smart wearable systems: Current status and future challenges. Artificial Intelligence in Medicine, 56, pp. 137–156.

Chappin, M.M., Hekkert, M.P., Meeus, M.T., and Vermeulen, W.J. (2008) The intermediary role of an industry association in policy-making processes: the case of the Dutch paper and board industry. Journal of Cleaner Production, 16 (14), pp.1462-1473. Available from: https://doi.org/10.1016/j.jclepro.2007.08.004 [Accessed 22nd October 2022]

Chatterjee, A. (2015) India's Handloom Challenge: Anatomy of a Crisis. Economic and Political Weekly, 50 (32), pp. 34 - 38. Available from: https://www.jstor.org/stable/pdf/24482525.pdf?refreqid=excelsior%3A956de43638ca84360fcfe1af4f6d16bb&ab_segments=&origin=&acceptTC=1 [Accessed 22nd October 2022]

Chunhavuthiyanon, M., and Intarakumnerd, P. (2014) The role of intermediaries in sectoral innovation system: The case of Thailand's food industry. International Journal of Technology Management & Sustainable Development, 13 (1), pp.15-36.

Cohen, W. M., and Levinthal, D. A. (1990) Absorptive capacity: A new perspective on learning and innovation. Administrative Science Quarterly, 35 (1), pp. 128–152. Available from: https://doi.org/10.2307/2393553 [Accessed 22nd October 2022]

Cohen, W. M., Nelson, R. R., and Walsh, J. P. (2002) Links and impacts: The influence of public research on industrial R&D. Management Science, 48 (1), pp. 1–23. Available from: https://doi.org/10.1287/mnsc.48.1.1.14273 [Accessed 22nd October 2022]

Cooke, P., Gomez Uranga, M. G., and Etxebarria, G. (1997) Regional innovation systems: Institutional and organizational dimensions. Research Policy, 26 (4-5), pp. 475–491. Available from: https://doi.org/10.1016/S0048-7333(97)00025-5 [Accessed 22nd October 2022]

Cortina, J.M. (1993) What is Coefficient Alpha? An Examination of Theory and Applications. Journal of Applied Psychology, 78, pp.98-104.

Cowan, R., David, P. A., and Dominique, F. (2000) The explicit economics of knowledge codification and tacitness. Industrial and Corporate Change, 9 (2), pp. 211–253. Available from: https://doi.org/10.1093/icc/9.2.211 [Accessed 22nd October 2022]

CRISIL Research (2021) Structural Stitch. Available from: https://www.crisil.com/en/home/our-analysis/views-and-commentaries/2021/07/structural-stitch.html [Accessed 12th August 2022]

Da Silveira Luz, M., and Monteiro Salles-Filho, S. L. (2011) Technological and productive density in sectoral innovation systems: The case of the Brazilian Aeronautics Industry. Journal of Technology Management and Innovation, 6 (4), pp. 60–72. Available from: https://doi.org/10.4067/S0718-27242011000400005 [Accessed 22nd October 2022]

Dai, Y., Haakonsson, S., and Oehler, L. (2020) Catching up through green windows of opportunity in an era of technological transformation: Empirical evidence from the Chinese wind energy sector. Industrial and Corporate Change, 29 (5), pp.1277-1295.

Dalenogare, L.S., Benitez, G.B., Ayala, N.F., and Frank, A.G. (2018) The expected contribution of Industry 4.0 technologies for industrial performance. Int. J. Prod. Econ., 204, 383–394. Available from: https://doi.org/10.1016/j.ijpe.2018.08.019 [Accessed 20th June 2022].

Damle, A. (2019). Seamless transitions. Available from: https://medium.com/@indiamigration/seamless-transitions-c0b0def43eaf [Accessed 16th October 2022]

Doak, S., and Assimakopoulos, D. (2007) How do forensic scientists learn to become competent in casework reporting in practice: A theoretical and empirical approach. Forensic science international, 167 (2-3), pp. 201-206.

Deloitte (2018a) Toward the next horizon of Industry 4.0. Accelerating transformation through collaboration and startups. Available from: IL327_Toward-thenext-horizon.pdf (deloitte.com) [Accessed 20th September 2021]

Deloitte (2018b) Unlocking Industry 4.0 potential. Transforming through startup-manufacturer collaborations and the unique role of the Israeli startup ecosystem. Available from: 74d8a3d1-4ade4196-889d-044e47c5d93c (admiralcloud.com) [Accessed 20th September 2021]

DeMars, C. E., and Erwin, T. D. (2005) Neutral or unsure: Is there a difference? Poster presented at the annual meeting of the American Psychological Association, Washington, DC.

De Meyer, A. C. (1985) The flow of technological innovation in an R & D department. Research Policy, 14 (6), pp. 315-328.

Department of Science & Technology (2014) Understanding Innovation: Indian National Innovation Survey Report. Available from: http://nationalinnovationsurvey.nstmis-dst.org/download/indian-national-innovation-survey-report.pdf [Accessed 16th January 2022]

Department of Water Resources, River Development and Ganga Rejuvenation (2020) Technical Textiles Manual. Available from: http://jalshakti-dowr.gov.in/sites/default/files/Technical_Textile_Practice_Manual.pdf [Accessed 22nd October 2022]

Desai, A. V. (1985) Market structure and technology: Their interdependence in Indian industry. Research Policy, 14 (3), pp. 161–170. Available from: https://doi.org/10.1016/0048-7333(85)90014-9 [Accessed 22nd October 2022]

Dewan, N. (2022) Pocketing even 1% market share from China means India gets a $10-billion opportunity in textiles, says industry. ET Online. 29th January 2022. Available from: https://economictimes.indiatimes.com/small-biz/trade/exports/insights/pocketing-even-1-market-share-from-china-means-india-gets-a-10-billion-opportunity-in-textiles-says-industry/articleshow/89193697.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst [Accessed 16th October 2022]

DFU (2022) The emergence of industry 4.0 technologies in 'Textiles and Apparels'. Available from: https://www.dfupublications.com/categories/article/the-emergence-of-industry-4-0-technologies-in-textiles-apparels [Accessed 6th August 2022].

Dimelis, S. P., and Papaioannou, S. K. (2011) ICT growth effects at the industry level: A comparison between the US and the EU. Information Economics and Policy, 23 (1), pp. 37-50.

Dosi, G. (1988) The nature of the innovative process. In: Dosi, G., Freeman, C., Nelson, R. R., Silverberg, G., and Soete, L. (eds.), Technical Change and Economic Theory (pp. 221-238). London: Pinter

Dosi, G., and Nelson, R. R. (2010) Technical change and industrial dynamics as evolutionary processes. Handbook of the Economics of Innovation, pp. 51–127. Available from:

https://doi.org/10.1016/S0169-7218(10)01003-8 [Accessed 22nd October 2022]

Dosi, G., Marengo, L., and Pasquali, C. (2006) How much should society fuel the greed of innovators? Research Policy, 35 (8), pp. 1110–1121. Available from: https://doi.org/10.1016/j.respol.2006.09.003 [Accessed 22nd October 2022]

Dzisah, J., and Etzkowitz, H. (2008) Triple Helix circulation: The heart of innovation and development. International Journal of Technology Management and Sustainable Development, 7 (2), pp. 101–115. Available from: https://doi.org/10.1386/ijtm.7.2.101_1 [Accessed 22nd October 2022]

Dziuban, C.D., and Shirkey, E.S. (1974) When is a Correlation Matrix Appropriate for Factor Analysis? Some Decision Rules. Psychological Bulletin, 81, pp.358-361.

Edquist, C. (1997) Systems of innovation: Technologies, institutions, and organisations. Pinter Publisher Ltd.

Edquist, C. (2005) Systems of innovation. Challenges and perspectives. In: Fagerberg, J., Mowery D., and Nelson R. R. (eds.) Oxford Hanbook of innovation. Oxford University Press.

Eisenhardt, K.M., and Martin, J. A. (2000) Dynamic capabilities: what are they? Strategic Management Journal; 21:1105-21.

EP-Textiles Coordination Division, Department of Commerce, Government of India (n.d.) Available from: https://commerce.gov.in/about-us/divisions/export-products-division/ep-textile/ [Accessed 22nd October 2022]

Etzkowitz, H. (2000) Tech transfer, incubators probed at Triple Helix III. Research-Technology Management, 43 (6), pp. 4–5.

Etzkowitz, H. (2002) Networks of innovation: Science, technology and development in the triple helix era. International Journal of Technology Management and Sustainable Development, 1 (1), pp. 7–20. Available from: https://doi.org/10.1386/ijtm.1.1.7 [Accessed 22nd October 2022]

Etzkowitz, H. (2003a) Innovation in innovation: The Triple Helix of university–industry–government relations. Social Science Information. Vol 42, pp. 293–338.

Etzkowitz, H. (2003b) MIT and the Rise of Entrepreneurial Science. Routledge.

Etzkowitz, H. (2008) The Triple Helix: University-industry-government innovation in action. Routledge.

Etzkowitz, H. (2017) Innovation Lodestar: The entrepreneurial university in a stellar knowledge firmament. Technological Forecasting and Social Change, 123 (4), pp. 122–129. Available from: https://doi.org/10.1016/j.techfore.2016.04.026 [Accessed 22nd October 2022]

Etzkowitz, H., and Leydesdorff, L. (1995) The Triple Helix: University–industry–government relations: A laboratory for knowledge-based economic development. EASST Review, 14, pp. 14–19.

Etzkowitz, H., and Leydesdorff, L. (2000) The dynamics of innovation: From National Systems and "Mode 2'" to a Triple Helix of university–industry–government relations. Research Policy, 29 (2), pp. 109–123. Available from: https://doi.org/10.1016/S0048-7333(99)00055-4 [Accessed 22nd October 2022]

Etzkowitz, H., Webster, A., Gebhardt, C., and Terra, B. R. C. (2000) The future of the university and the university of the future: Evolution of ivory tower to entrepreneurial paradigm. Research Policy, 29 (2), pp. 313–330. Available from: https://doi.org/10.1016/S0048-7333(99)00069-4 [Accessed 22nd October 2022]

Fagerberg, J., and Srholec, M. (2008) National innovation systems, capabilities and economic development. Research Policy, 37 (9), pp. 1417–1435. Available from: https://doi.org/10.1016/j.respol.2008.06.003 [Accessed 22nd October 2022]

Fagerberg, J., Lundvall, B. Å., and Srholec, M. (2017) Global value chains, national innovation systems and economic development. Lunds University Papers in Innovation Studies, paper no. 2017/15.

Federation of Indian Chambers of Commerce and Industry (FICCI) (n.d) FICCI Note on Pressing Issues of India Textiles Industry. Available from: https://ficci.in/SEDocument/20332/Arun-Jailtley_Enclosure.pdf [Accessed 5th August 2022].

Federation of Indian Chambers of Commerce and Industry (FICCI) (2013) FICCI's Suggestions for National Textile Policy 2013. Available from: https://ficci.in/sedocument/20275/ficci-suggestions-for-ntp2013.pdf [Accessed 7th August 2022].

Fibre2Fashion (2022) Production halts in AP mills; global recession hit Indian textiles. Available from: https://www.fibre2fashion.com/news/textile-news/production-halts-in-ap-mills-global-recession-hit-indian-textiles--283576-newsdetails.htm [Accessed 16th October 2022]

Field, A. P. (2005) Discovering statistics using SPSS (2nd edition). London: Sage, Available from: http://users.sussex.ac.uk/~andyf/factor.pdf [Accessed 22nd October 2022]

Forbes, N., and Wield, D. (2000) Managing R&D in technology-followers. Research Policy, 29 (9), pp. 1095–1109. Available from: https://doi.org/10.1016/S0048-7333(99)00071-2 [Accessed 22nd October 2022]

Foxon, T. (2003) Inducing Innovation for a low-carbon future: Drivers, barriers and policies – A report for the Carbon Trust. Carbon Trust.

Freeman, C. (1987) Technology policy and economic performance: Lessons from Japan. London: Printer.

Freeman, C. (1995) The National System of Innovation in historical perspective. Cambridge Journal of Economics, 19 (1), pp. 5–24.

Freeman, C., and Louca, F. (2001). As time goes by: From the industrial revolutions to the information revolution. Oxford University Press.

Gaur, S., (1997) Adelman and Morris Factor Analysis of Developing Countries. Journal of Policy Modeling, 19 (4), pp. 407-415.

George, D., and Mallery, P. (2003) SPSS for Windows Step by Step: a Simple Guide and Reference. 11.0 update. 4th ed. Boston: Allyn & Bacon.

Ghosh, J. (2000) The Impact of Government Policies on the Textile and Garment Industries of India. University of Wisconsin-Whitewater. Available from: https://wisconsingeography.files.wordpress.com/2013/05/1999-2000-volume-15-16-the-impact-of-government-policies-on-the-textile-and-garment-industries-of-india.pdf [Accessed 8th August 2022]

Giachetti, C., and Marchi, G. (2017) Successive changes in leadership in the worldwide mobile phone industry: The role of windows of opportunity and firms' competitive action. Research Policy, 46 (2), pp. 352–364. Available from: https://doi.org/10.1016/j.respol.2016.09.003 [Accessed 22nd October 2022]

Giri, S., and Rai, S.S. (2013) The Dynamics of Grament Supply Chain. International Journal of Managing Value and Supply Chains, 4 (4), pp. 29-42, Available online at: https://airccse.org/journal/mvsc/papers/4413ijmvsc03.pdf [Accessed 22nd October 2022]

GIZ (2016) Innovative Approaches to Private Sector Development. Private Sector Development Newsletter. Available from: https://www.giz.de/en/downloads/giz2016-en-GIZ_Private_Sector_Development_Newsletter_No.9.pdf

G. Pratap and C. Naidu (2015) Socio-Economic conditions of the Handloom weavers Vontimita Mandal in Kadapa district of Andhra Pradesh. International Journal of Management Studies and Research, 3 (1), pp. 5-11, Available from : https://www.arcjournals.org/pdfs/ijmsr/v3-i1/2.pdf [Accessed 22nd October 2022]

Gopalakrishnan, B. N. (2017) Structure of India's Textile and Apparel Sector. Economic and Environmental Policy Issues in Indian Textile and Apparel Industries, Springer, pp 17-45. Available from: https://doi.org/10.1007/978-3-319-62344-3_3 [Accessed 10th August 2022].

Grant Thornton & CII (2017) India's Readiness for Industry 4.0. A Focus on Automotive Sector. Available from: https://www.grantthornton.in/globalassets/1.-member-firms/india/assets/pdfs/indias_readiness_for_industry_4_a_focus_on_automotive_sector.pdf [Accessed 28th August 2021].

Hall, A., Mytelka, L., and Oyeyinka, B. (1997) Innovation systems: Implications for agricultural policy and practice. ILAC Brief.

Hanel, P., and St-Pierre, M. (2006) Industry-university collaboration by Canadian manufacturing firms. Journal of Technology Transfer, 31 (4), pp. 485–499. Available from: https://doi.org/10.1007/s10961-006-0009-5 [Accessed 22nd October 2022]

Hansen, T. and Hansen, U. E. (2021) How many firms benefit from a window of opportunity? Knowledge spillovers, industry characteristics, and catching up in the Chinese biomass power plant industry. Industrial and Corporate Change, 29 (5), pp. 1211–1232. Available from: https://doi.org/10.1093/icc/dtaa008 [Accessed 22nd October 2022]

Hauknes, J. and Nordgren, L. (1999) Economic rationales of government involvement in innovation and the supply of innovation-related services.

Hekkert, M. P., Suurs, R. A. A., Negro, S. O., Kuhlmann, S., and Smits, R. E. H. M. (2007) Functions of innovation systems: A new approach for analyzing technological change. Technological Forecasting and Social Change, 74 (4), pp. 413–432. Available from: https://doi.org/10.1016/j.techfore.2006.03.002 [Accessed 22nd October 2022]

Hjort, J., and Poulsen, J. (2019) The arrival of fast Internet and employment in Africa. NBER Working Paper no. w23582. American Economic Review, vol. 109, no. 3, pp. 1032–1079. Available from: https://doi.org/10.1257/aer.20161385 [Accessed 22nd October 2022]

Holtkamp, B., and Iyer, A. (2017) Industry 4.0: The Future of Indo-German Industrial Collaboration.

IIT Delhi (2008) Memorandum of Understanding for setting up of a Centre of Excellence for Protech Segment of Technical Textile between Indian Institute of Technology Delhi (IITD) and NITRA, Ghaziabad. Available from: https://home.iitd.ac.in/uploads/mou/NITRA_MOU.pdf [Accessed 3rd November 2022].

IIT Delhi (2020) Technical Textiles Industry in India-Opportunities and Challenges Baseline Study. Available from: http://texmin.nic.in/sites/default/files/Baseline_Survey_Technical_Textiles_Sector_20042022.pdf [Accessed 3rd November 2022]

PTI (2019) Wipro, IISc Together Developed India's First Metal 3D Printing Machine. Indian Startup News. 15th December 2019. Available from: https://indianstartupnews.com/news/wipro-iisc-indian-first-metal-3d-printing-machine/ [Accessed 22nd October 2022]

Indian Web2 (2015) 13 Govt. Venture Capital Firms for Startups in India. Available from: https://www.indianweb2.com/2015/01/13-govt-venture-capital-firms-for_14.html [Accessed 22nd October 2022]

Jacob, M. (2016) Innovation system and Agriculture: Going Beyond Research for Increasing Yields. In: Francis J., Mytelka L., Van Huis, A., and Röling N. (eds.) Innovation Systems: Towards Effective Strategies in support of Smallholder Farmers. Technical Centre for Agricultural and Rural Cooperation (CTA) & Wageningen University & Research(WUR)/Convergence of Sciences-Strengthening Innovation Systems (CoS-SIS), Wageninge.

Jansen, J.J., Van Den Bosch, F.A. and Volberda, H. W. (2006) Exploratory innovation, exploitative innovation, and performance: Effects of organizational antecedents and environmental moderators. Manage Sci; 52:1661-74.

Jensen, M. B., Johnson, B., Lorenz, E., and Lundvall, B. Å. (2007) Forms of knowledge and modes of innovation. Research Policy, 36 (5), pp. 680–693. Available from: https://doi.org/10.1016/j.respol.2007.01.006 [Accessed 22nd October 2022]

Joseph, K. J., and Abraham, V. (2009) University-industry interactions and innovation in India: Patterns, determinants, and

effects in select industries. Seoul Journal of Economics, 22 (4), pp. 467.

Kaiser, H.F. (1974) An Index of Factorial Simplicity. Psychometrika, 39, pp.31-36.

Kang, H., and Song, J. (2017) Innovation and recurring shifts in industrial leadership: Three phases of change and persistence in the camera industry. Research Policy, 46 (2), pp. 376–387. Available from: https://doi.org/10.1016/j.respol.2016.09.004 [Accessed 22nd October 2022]

Kanupriya (2021) Digitalization and the Indian textiles sector: A critical analysis. FIIB Business Review, 10 (3), pp. 196-201.

Kapoor, Radhicka (2016) Technology, jobs and inequality: Evidence from India's manufacturing sector. Working Paper, No. 313, Indian Council for Research on International Economic Relations (ICRIER), New Delhi. Available from: https://www.econstor.eu/bitstream/10419/176331/1/icrier-wp-313.pdf [Accessed 22nd October 2022]

Kapoor, Radhicka (2018) Understanding the Performance of India's Manufacturing Sector: Evidence from Firm Level Data. CSE Working Paper, 2018-2, Centre for Sustainable Employment, Azim Premji University, Bengaluru. Available from: https://cse.azimpremjiuniversity.edu.in/wpcontent/uploads/2018/05/Kapoor_Performance_ Organised_Manufacturing.pdf [Accessed 22nd October 2022]

Karlsen, A., Lund, H. B., and Steen, M. (2022) The roles of intermediaries in upgrading of manufacturing clusters: Enhancing cluster absorptive capacity. Competition and Change. Available from: https://doi.org/10.1177/10245294211059138 [Accessed 22nd October 2022]

Katrak, H. (1985) Imported technology, enterprise size and R and D in a newly industrializing country: The Indian experience. Oxford Bulletin of Economics and Statistics, 47 (3), pp. 213–229. Available from: https://doi.org/10.1111/j.1468-0084.1985.mp47003003.x [Accessed 22nd October 2022]

Katz, R., and Tushman, M. (1981) An investigation into the managerial roles and career paths of gatekeepers and project supervisors in a major R & D facility. R&D Management, 11 (3), pp. 103-110.

Kim J.O., and Mueller, C.W. (1978) Factor analysis: Statistical methods and practical issues. Thousand Oaks, CA: Sage Publications, Quantitative Applications in Social Sciences Series, No. 14.

Kim, L. (1992) National System of Industrial Innovation: Dynamics of Capability Building in Korea. In R. Nelson (ed.): National Innovation Systems: A Comparative Analysis (pp. 357-383). New York: Oxford University Press.

Kim, L. (1992) National System of Industrial Innovation: Dynamics of Capability Building in Korea. In R. Nelson (ed.): National Innovation Systems: A Comparative Analysis (pp. 357-383). New York: Oxford University Press.

Kline, P. (1999) The Handbook of Psychological Testing. 2nd ed. London: Routledge.

Khan, M. (2022) Socio-Economic condition of Handloom weavers – A case study of Chirala Mandal, Andhra Pradesh. IOSR Journal of Economics and Finance, 11 (4), pp. 66-75, DOI: 10.9790/5933-1104016675 [Accessed 22nd October 2022]

KPMG (2019) Technical textiles: Growth engine of Indian textiles sector: TECNOTEX 2019. August 29-31, 2019. Bombay Exhibition Centre, Mumbai.

Koria, R., Bartels, F. L., Andriano, L., and Köszegi, S. (2014) Effectiveness and Efficiency of National Systems of Innovation: The importance of ICT, the Cases of Ghana and Kenya. IST-Africa Conference, 2014. IEEE Publications.

Kucirkova, A. (2019) The Ultimate Guide: Everything You Need to Know About Industry 4.0. 8 (1). Available from: The Ultimate Guide: Everything You Need to Know About Industry 4.0 - Triple Helix Association [Accessed 25th August 2021]

Kumar, N., and Siddharthan, N. S. (2013) Technology, market structure and internationalization: Issues and policies for developing countries. Routledge.

Kumar, N., and Siddharthan, N. S. (1994) Technology, firm size and export behaviour in developing countries: The case of Indian enterprises. Journal of Development Studies, 31 (2), pp. 289–309. Available from: https://doi.org/10.1080/00220389408422362 [Accessed 22nd October 2022]

Krishnan, N. (2022) A Study on Growth of Textile and Apparel Industry in India. International Journal of Novel Research and Development (IJNRD). 7 (2), pp. 75-93.

Lakshmanan, R., and Nayyar, M. (2020) Personal Protective Equipment in India: An INR 7,000 Cr industry in the making. Available from: https://www.investindia.gov.in/siru/personal-protective-equipment-india-INR-7000-cr-industry-in-the-making [Accessed 22nd October 2022]

Lall, S., and Kumar, R. (1981) Firm-level export performance in an inward-looking economy: The Indian engineering industry. World Development, 9 (5), pp. 453–463. Available from: https://doi.org/10.1016/0305-750X(81)90038-3 [Accessed 22nd October 2022]

Lata V. (2021) Silk Industry in India: The Story Behind the Sheen of the Indian Queen of Textiles. Available from: https://www.teriin.org/article/silk-industry-india-story-behind-sheen-indian-queen-textiles [Accessed 15th November 2022].

Lau, C. M., and Ngo, H. Y. (2004) The HR system, organizational culture, and product innovation. International business review, 13 (6), pp. 685-703.

Lee, K., and Ki, J. (2017) Rise of latecomers and catch-up cycles in the world steel industry. Research Policy, 46 (2), pp. 365–375. Available from: https://doi.org/10.1016/j.respol.2016.09.010 [Accessed 22nd October 2022]

Lee, K., and Malerba, F. (2017) Catch-up cycles and changes in industrial leadership: windows of opportunity and responses of firms and countries in the evolution of sectoral systems. Research Policy, 46 (2), pp. 338–351. Available from: https://doi.org/10.1016/j.respol.2016.09.006 [Accessed 22nd October 2022]

Lema, R., Fu, X., and Rabellotti, R. (2020) Green windows of opportunity: latecomer development in the age of transformation toward sustainability. Industrial and Corporate Change, 29 (5), pp. 1193-1209.

Letaba, P. (2019) Relationship between Dominant Triple Helix Model and Type of Intermediary Organizations. 1-6. Available from: 10.23919/ PICMET.2019.8893910 [Accessed 25th August 2021].

Leydesdorff, L., and Van den Besselaar, P. (1994) Evolutionary Economics and Chaos Theory: New directions in technology studies. London Pinter Publishers.

Leydesdorff, L. (1997) Why words and co-words cannot map the development of the sciences. Journal of the American Society for Information Science, 48 (5), pp. 418–427. Available from: https://doi.org/10.1002/(SICI)1097-4571(199705)48:5<418::AID-ASI4>3.0.CO;2-Y [Accessed 22nd October 2022].

Leydesdorff, L. (2001) Knowledge-based innovation systems and the model of a triple helix of university-industry-government relations. Conference on New Economic Windows: New Paradigms for the New Millennium, Salerno, Italy, September.

Leydesdorff, L. (2004) The university-industry knowledge relationship: Analyzing patents and the science base of technologies. Journal of the American Society for Information Science and Technology, 55 (11), pp. 991–1001. Available from: https://doi.org/10.1002/asi.20045 [Accessed 22nd October 2022].

Leydesdorff, L. (2005) The triple helix model and the study of knowledge-based innovation systems. International Journal of Contemporary Sociology, 42 (1).

Leydesdorff, L. (2012) The triple helix, quadruple helix,…, and an N-tuple of helices: explanatory models for analyzing the knowledge-based economy?. Journal of the knowledge economy, 3 (25-35).

Leydesdorff, L. &Etzkowitz, H. (1998a) The Triple Helix as a Model for Innovation Studies. Science & Public Policy, 25(3), pp. 195-203.

Leydesdorff, L. & Etzkowitz, H. (1998b) Triple Helix of innovation: introduction. Science and Public Policy 25, pp. 358–364.

Ligarski, Mariusz J., Rożałowska, B., and Krzysztof K. (2021). A Study of the Human Factor in Industry 4.0 Based on the Automotive Industry. Energies 14.20 (2021): 6833.

Lippman, S. A., and Rumelt, R. P. (2003) A bargaining perspective on resource advantage. Strategic Management Journal, 24 (11), pp. 1069-1086.

Li, Y., and Zahra, S. A. (2012) Formal institutions, culture, and venture capital activity: A cross country analysis. Journal of Business Venturing, 27 (1), pp. 95–111. Available from: https://doi.org/10.1016/j.jbusvent.2010.06.003 [Accessed 22nd October 2022].

Lok Sabha Secretariat, Parliament Library and Reference, Research, Documentation and Information Service (LARRDIS) (2014). Technology Up gradation Fund Scheme (TUFS) for Textile Sector. Available from: http://164.100.47.193/Refinput/New_Reference_Notes/English/TUFS.pdf [Accessed 7th August 2022].

Lundvall, B. (1985) Product Innovation and UserProducer Interaction. Industrial Development Research Series No. Available from: (PDF) Product Innovation and User-Producer Interaction (researchgate.net) [Accessed 31st August 2021].

Lundvall, B. Å. (1992) National Systems of Innovation: Towards a Theory of Innovation and Interactive learning. London: Printer.

Lundvall, B. Å. (2007) National innovation systems – Analytical concept and development tool. Industry and Innovation, 14 (1), pp. 95–119. Available from: https://doi.org/10.1080/13662710601130863 [Accessed 22nd October 2022]

Lundvall, B.-Å. (2016) National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning. In B.-Å. Lundvall (ed): From the economics of knowledge to the learning economy, pp. 85-106. London, Anthem Press.

Macdonald, S., and Williams, C. (1993) Beyond the boundary: an information perspective on the role of the gatekeeper in the organization. Journal of Product Innovation Management, 10 (5), pp. 417-427.

Maiti, D., Castellacci, F., and Melchior, A. (2020) Digitalisation and development: Issues for India and beyond. Available from: https://doi. org/10.1007/978-981-13-9996-1_1 [Accessed 16th October 2022]

Majumdar, A., Garg, H., and Jain, R. (2021) Managing the barriers of Industry 4.0 adoption and implementation in textile and clothing industry: Interpretive structural model and triple helix framework. Computers in Industry, 125 (2021): 103372

Malerba, F. (2002) Sectoral systems of innovation and production. Research Policy, 31 (2), pp. 247–264. Available from: https://doi.org/10.1016/S0048-7333(01)00139-1 [Accessed 22nd October 2022]

Malerba, F. (2004) Sectoral systems of innovation: Concepts, issues and analyses of six major sectors in Europe. Cambridge University Press.

Malerba, F., and Mani, S. (eds.) (2009) Sectoral systems of innovation and production in developing countries: actors, structure and evolution. Edward Elgar Publishing.

Malerba, F., and Nelson, R. R. (2011) Learning and catching up in different sectoral systems: Evidence from six industries. Industrial and Corporate Change, 20 (6), pp. 1645–1675. Available from: https://doi.org/10.1093/icc/dtr062 [Accessed 22nd October 2022]

Malerba, F., and Nelson, R. R. (2013) Economic development as a learning process: Variation across sectoral systems. Edward Elgar Publishing.

Mani, S. (2005) The Dragon vs. the Elephant Comparative analysis of innovation capability in the telecommunications equipment industry in China and India. Center for Development Studies Working Paper No. 279.

Mani, S. (2016) New IPR Policy 2016: Not Based on Evidence. Economic and Political Weekly, pp. 28-32.

Maran, T. (2009) Need for relook at National Jute Policy. Available from: https://www.fibre2fashion.com/news/textile-news/newsdetails.aspx?news_id=77925 [Accessed 10th August 2022].

Martin, B. R., and Etzkowitz, H. (2000) The origin and evolution of the university species. SPRU Electronic Working Paper Series, paper 59.

Martinez, F. (2019) Process excellence the key for digitalization. Business Process Management Journal, 25 (7), 1716–1733. Available from: https://doi.org/10.1108/BPMJ-08-2018-0237 [Accessed 16th October 2022]

Mathai, P. G. (2013) Government new policy offers ailing Textile industry ray of hope. Available from: https://www.indiatoday.in/magazine/economy/story/19850630-government-new-policy-offers-ailing-textile-industry-ray-of-hope-770177-2013-12-20 [Accessed 8th August 2022].

McMillan, M., Rodrik, D., and Verduzco, I. (2014) Globalization, structural change and productivity growth, with an update on Africa. World Development, 63, pp. 11–32.

Miller, D., and Friesen, P. H. (1983) Strategy-making and environment: the third link. Strategic management journal. 4 (3), pp. 221-35.

Ministry of Commerce & Industry (2021) PM Gati Shakti– National Master Plan for Multi Modal connectivity to various Economic Zones. Available from: https://dpiit.gov.in/logistics-division [Accessed 22nd October 2022]

Ministry of External Affairs (2020) India FDI Boost through Conducive Government Policies. Available from: https://indbiz.gov.in/india-fdi-boost-through-conducive-government-policies/ [Accessed 22nd October 2022]

Ministry of Heavy Industries (2022) Capital Goods Scheme. Available from: https://heavyindustries.gov.in/UserView/index?mid=1377 [Accessed 22nd October, 2022]

Ministry of Textiles (2000) National Textile Policy, 2000. Available from: http://texmin.nic.in/sites/default/files/policy_2000.pdf [Accessed 6th August 2022].

Ministry of Textiles. (2005) National Jute Policy 2005. Available from: http://texmin.nic.in/sites/default/files/jutepolicy2005.pdf [Accessed 6th August 2022].

Ministry of Textiles (2010) National Fibre Policy (2010 – 11). Available from: https://jute.com/documents/19204/25104/Fibre_Policy_dir_mg_d_20100608.pdf/86c73cde-6a77-4f19-b6df-f38a71bc31bd [Accessed 5th August 2022].

Ministry of Textiles (2013) Integrated Scheme for Powerloom Sector Development. Available from: http://www.txcindia.gov.in/html/ISPSD%20Scheme%20Details.pdf [Accessed 4th August 2022].

Ministry of Textiles (2014) Annual Report 2013-14. Available from: http://texmin.nic.in/sites/default/files/ar_13_14_english.pdf [Accessed 8th August 2022]

Ministry of Textiles (2015) Scheme for Research and Development for the Textiles Industry including Jute. Available from: http://jutecomm.gov.in/Documents/R&D%20Schemes%20of%20MOT/Research%20and%20Development%20for%20the%20Textiles%20Industry%20including%20Jute%20for%20a%20period%20of%20five%20years%20from%202014-15%20to%202018-19.pdf [Accessed 10th August 2022].

Ministry of Textiles (n.d.) Comprehensive Powerloom Cluster Development Scheme (CPCDS). Available from: http://texmin.nic.in/sites/default/files/11b_Guidelines_of_development_of_mega_cluster_scheme_Powerloom_nmcc_cs_20090312_0.pdf [Accessed 5th August 2022].

Ministry of Textile (n.d.) Guidelines for National Handicrafts Development Programme (NHDP). Available from: http://www.handicrafts.nic.in/pdf/Scheme.pdf#page=1 [Accessed 8th August 2022].

Ministry of Textiles (n.d.) Jute Technology Mission. Available from: http://texmin.nic.in/sites/default/files/jute_technology_mission_09012015.pdf [Accessed 6th August 2022].

Ministry of Textiles (n.d.) NER Textile Promotion Scheme 2017 – 2020. Available from: http://texmin.nic.in/sites/default/files/NERTPS%20guidelines%2011.04.18.pdf [Accessed 5th August 2022].

Ministry of Textiles (n.d.) PowerTex India (Comprehensive Scheme for Powerloom Sector Development). Available from: http://texmin.nic.in/sites/default/files/PowerTex%20India%20Brochure%20English.pdf [Accessed 4th August 2022].

Ministry of Textiles (n.d.) Revised Comprehensive Powerloom Cluster Development Scheme (CPCDS). Available from: http://texmin.nic.in/sites/default/files/Revised%20CPCDS%20guidelines.pdf [Accessed 6th August 2022].

Ministry of Textile (n.d.) Samarth Scheme for Capacity Building in Textile Sector under the skill India Mission 2017-2020. Available from: http://texmin.nic.in/sites/default/files/Guidelines%20for%20samarth-Scheem%20for%20capacity%20Building%20in%20Textiles%20Sector%20%28SCBTS%29%20%281%29.pdf [Accessed 7th August 2022].

Ministry of Textiles (n.d.) Working Group Report on Handicrafts for 12th Five Year Plan, 2012. Available from: https://niti.gov.in/planningcommission.gov.in/docs/aboutus/committee/wrkgrp12/wg_handi1101.pdf [Accessed 3rd August 2022].

Ministry of Textiles (2016) Amended Technology Upgradation Fund Scheme. Available from: http://texmin.nic.in/sites/default/files/Atufs_resolution_0.pdf [Accessed 9th August 2022].

Ministry of Textiles (2016) Material on Technical Textiles. Available from:

http://texmin.nic.in/sites/default/files/scheme_technical_textile_070116.pdf [Accessed 22nd October 2022]

Ministry of Textiles (2018) Zero Defect, Zero Effect - Mantra of Textile Ministry. Available from: https://pib.gov.in/newsite/PrintRelease.aspx?relid=186673 [Accessed 6th August 2022].

Ministry of Textile (2019) Integrated Skill Development Scheme in the Textile Sector. Available from: https://pib.gov.in/PressReleseDetail.aspx?PRID=1593031 [Accessed 6th August 2022].

Ministry of Textiles (2021) Compendium of Handloom Schemes. Available from: http://handlooms.nic.in/assets/img/Handloom%20Schemes/final%20book%208%20Nov%2021.pdf [Accessed 7th August 2022].

Ministry of Textiles (2021) Material for incorporation in the Annual Report of the Ministry of Textiles. Available from: http://texmin.nic.in/sites/default/files/note_on_indian_textile_and_clothing_exports_intl_trade_section_0.pdf [Accessed 22nd October 2022].

Ministry of Textile (2022) Achievements of JTM Schemes. Available from: https://jute.com/web/guest/scheme-initiatives-and-achievements/achievements-of-jtm-schemes [Accessed 8th August 2022].

Ministry of Textile (2022) Annual Report 2021-22. Available from: http://texmin.nic.in/sites/default/files/AR_Ministry_of_Textiles_%202021-22_Eng.pdf [Accessed 9th August 2022].

Ministry of Textiles (2022) Indian Handloom Brand Scheme Available from: https://www.indiahandloombrand.gov.in/pages/background [Accessed 7th August 2022].

Mint (2021) The new Indian Tech-xtile Industry. Available from: https://www.livemint.com/brand-post/the-new-indian-tech-xtile-industry-11626430129048.html [Accessed 7th August 2022].

Mint (2022) Textiles ministry clears 20 strategic projects worth ₹74 crores. Available from: https://www.livemint.com/news/india/textiles-ministry-clears-20-strategic-projects-worth-rs-74-crore-11667375405734.html

Mishra, S., and Gupta, A. (2019) A study on the present condition of Handloom weavers : A Review. International Journal of Interdisciplinary Research and Innovations, 7 (2), pp. 325-331, Available from: https://www.researchgate.net/publication/344161255_A_STUDY_ON_THE_PRESENT_CONDITION_OF_THE_WEAVERS_OF_HANDLOOM_INDUSTRY_A_REVIEW [Accessed 1st November 2022].

Morrison, A., and Rabellotti, R. (2017) Gradual catch up and enduring leadership in the global wine industry'. Research Policy, 46 (2), pp. 417–430. Available from: https://doi.org/10.1016/j.respol.2016.09.007 [Accessed 1st November 2022].

Moschitz, H., Roep, D., Brunori, G., and Tisenkopfs, T. (2015) Learning and innovation networks for sustainable agriculture: Processes of co-evolution, joint reflection and facilitation. Journal of Agricultural Education and Extension, 21 (1), pp. 1–11. Available from: https://doi.org/10.1080/1389224X.2014.991111 [Accessed 1st November 2022].

Mowery, D.C. (2009) Plus ca change: Industrial R&D in the "third industrial revolution. Industrial and corporate change, 18 (1), pp.1-50. Available from: https://doi.org/10.1093/icc/dtn049 [Accessed 22nd October 2022]

MSME Department, Govt. of Tamil Nadu (2018) Salient features and Guidelines of Innovation Voucher Program (IVP). Available from: http://cms.tn.gov.in/sites/default/files/go/msme_e_17_2018.pdf [Accessed 22nd October 2022]

Mu, Q., and Lee, K. (2005) Knowledge diffusion, market segmentation and technological catch-up: The case of the telecommunication industry in China. Research Policy, 34 (6), pp. 759–783. Available from: https://doi.org/10.1016/j.respol.2005.02.007 [Accessed 22nd October 2022]

Muchie, M., and Baskaran, A. (eds.) (2017) Sectoral innovation systems in Africa. Africa World Press.

Mytelka, L. K., and Smith, K. (2002) Policy learning and innovation theory: An interactive and co-evolving process. Research Policy, 31 (8–9), pp. 1467–1479. Available from: https://doi.org/10.1016/S0048-7333(02)00076-8 [Accessed 22nd October 2022]

Nakwa, K., Zawdie, G., and Intarakumnerd, P. (2012) Role of intermediaries in accelerating the transformation of inter-firm networks into triple helix networks: A case study of sme-based industries in Thailand. Procedia-Social and Behavioral Sciences, 52, pp.52-61.

Nandagopal, M., Gala, K., and Premnath V. (2011) Improving technology commercialization at research institutes: Practical insights from NCL Innovations. Innovation Educators' Conference (IEC), Indian School of Business, Hyderabad. Available from: https://www.venturecenter.co.in/pdfs/ISB-Conf-Paper-ver04.pdf [Accessed 22nd October 2022]

National Institute of Fashion Technology (2022) RTC Project. Available from: https://www.nift.ac.in/sites/default/files/2022-09/TOR%20for%20RTC%20Project.pdf [Accessed 22nd October 2022]

Negro, S. O., Suurs, R. A. A., and Hekkert, M. P. (2008) The bumpy road of biomass gasification in the Netherlands: Explaining the rise and fall of an emerging innovation system. Technological Forecasting and Social Change, 75 (1), pp. 57–77. Available from: https://doi.org/10.1016/j.techfore.2006.08.006 [Accessed 22nd October 2022]

Nelson, R.R. (1985) An evolutionary theory of economic change. Harvard university press.

Nelson, R. R. (1993) National Innovation Systems: A Comparative Analysis. Oxford University Press, New York.

Nelson, R. R., and Rosenberg, N. (1993) Technical Innovation and National Systems. In: Nelson, R. R. (1993) (ed.) National Innovation Systems: A Comparative Analysis (pp. 3-22). New York: Oxford University Press.

Nevzorova, T. (2021) Barriers, drivers and context environment of technological innovation An analysis of the biogas industry in Russia. KTH Royal Institute of Technology. Sweden. Available from: FULLTEXT01. pdf (diva-portal.org) [Accessed 30th October 2021].

Nguyen, H. and Harrison, N. (2019) Leveraging customer knowledge to enhance process innovation: moderating effects from market dynamics. Business Process Management Journal, 25 (2), pp. 307-322. Available from: https://doi.org/10.1108/BPMJ-03-2017-0076 [Accessed June 10th 2021].

NITI Aayog (2018) Strategy for New India @ 75, pp. 20-24. Available from: https://www.niti.gov.in/sites/default/files/2019-01/Strategy_for_New_India_2.pdf [Accessed 16th January 2023)

NITRA (n.d.) Instruments Developed. Available from: http://www.nitratextile.org/instruments-developed.php [Accessed 22nd October 2022]

NITRA (2021) R&D Projects 2020-21. Available from: http://www.nitratextile.org/pdf/R&D%20 projects%202020-21.pdf [Accessed 22nd October 2022]

NSTEDB (2002) Science & Technology Entrepreneurship Park (STEP). Available from: https://www.nstedb.com/institutional/step.htm [Accessed 22nd October 2022]

OECD (2009) Overcoming Barriers to Administrative Simplification Strategies guidance for policy makers. Available from: https://www.oecd.org/regreform/42112628.pdf [Accessed 30th August 2022].

OECD (2011) Policy Framework for Investment User's Toolkit. Available from: https://www.oecd.org/investment/toolkit/policyareas/publicgovernance/41890394.pdf [Accessed 30th August 2022].

OECD (2018) Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation, 4th Edition, Paris: OECD.

OECD (2022) Inflation & Consumer Price Index. Available from: https://data.oecd.org/price/inflation-cpi.htm. [Accessed 22nd October 2022]

Parameswaran, M. (2004) Economic reforms, technical change and efficiency change: Firm level evidence from capital goods industries in India. Indian Economic Review, pp. 239–260.

Paunov, C., and Rollo, V. (2016) Has the Internet fostered inclusive innovation in the Developing World? World Development, 78, pp. 587–609. Available from: https://doi.org/10.1016/j.worlddev.2015.10.029 [Accessed 22nd October 2022]

Perez, C. (1983) Structural change and assimilation of new technologies in the economic and social systems. Futures, 15 (5), pp. 357–375. Available from: https://doi.org/10.1016/0016-3287(83)90050-2 [Accessed 22nd October 2022]

Perkmann, M., and Walsh, K. (2007) University-industry relationships and open innovation: Towards a research agenda. International Journal of Management Reviews, 9 (4), pp. 259–280. Available from: https://doi.org/10.1111/j.1468-2370.2007.00225.x [Accessed 22nd October 2022]

Perkmann, M., Salandra, R., Tartari, V., McKelvey, M. and Hughes, A. (2021) Academic engagement: A review of the literature 2011-2019. Research Policy, 50(1), pp. 104114.

Pessot, E., Zangiacomi, A., Battistella, C., Rocchi, V., Sala, A., and Sacco, M. (2020) What matters in implementing the factory of the future: Insights from a survey in European manufacturing regions. Journal of Manufacturing Technology Management. Available from: https://doi.org/10.1108/JMTM-05-2019- 0169 [Accessed 16th October 2022]

Press Information Bureau (PIB) (2017) DRDO Transfers Technology for Bullet Proof Jacket. Available from: https://pib.gov.in/newsite/PrintRelease.aspx?relid=171391 [Accessed 7th October 2022]

Press Information Bureau (PIB) (2019) G.I. Tagged Products. Available from: https://pib.gov.in/Pressreleaseshare.aspx?PRID=1594198 [Accessed 7th October 2022]

Press Information Bureau (PIB) (2019) Integrated Textiles Park. Available from: https://pib.gov.in/PressReleasePage.aspx?PRID=1594200 [Accessed 22nd October 2022]

Press Information Bureau (PIB) (2021) Govt. announces launch of Mega Investment Textiles Parks (MITRA) scheme to make Indian textile industry globally competitive. Available from: https://pib.gov.in/Pressreleaseshare.aspx?PRID=1694058 [Accessed 7th October 2022]

Press Information Bureau (PIB) (2021) Government approves continuation of Rebate of State and Central taxes and Levies (RoSCTL) on Export of Apparel/ Garments and Made-ups. Available from: https://pib.gov.in/Pressreleaseshare.aspx?PRID=1735380 [Accessed 16th October 2022]

Press Information Bureau (PIB) (2021) Ministry of Textiles approves continuation of Comprehensive Handicrafts Cluster Development Scheme with a total outlay of Rs. 160 crore. Available from: https://pib.gov.in/PressReleasePage.aspx?PRID=1761118 [Accessed 22nd October 2022]

Press Information Bureau (PIB) (2022) India's Textiles Exports highest ever in FY 2021-22, Cross US$ 44 Bn. Available from: https://pib.gov.in/PressReleasePage.aspx?PRID=1829802 [Accessed 22nd October, 2022]

Press Information Bureau (PIB) (2022) Government Notifies Scheme on Enhancement of Competitiveness in the Indian Capital Goods Sector- Phase-II. Available from: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1793192 [Accessed 22nd October, 2022]

Press Information Bureau (PIB) (2022) Ministry of Textiles approved Pashmina Wool Development Scheme. Available from: https://www.pib.gov.in/PressReleasePage.aspx?PRID=1847885. [Accessed 5th October 2022]

Press Information Bureau (PIB) (2022) Make in India' completes 8 years, annual FDI doubles to USD 83 billion. Available from: https://pib.gov.in/PressReleasePage.aspx?PRID=1861929 [Accessed 22nd October 2022]

Press Information Bureau (PIB) (2022) Robust inter-ministerial coordination and cooperation is the need of the hour in paving a strong path for the development of technical textiles market in India: Smt. Darshna Jardosh. Available from: https://www.pib.gov.in/PressReleseDetailm.aspx?PRID=1853905 [Accessed 22nd October 2022]

Press Information Bureau (PIB) (2022) Skill India takes artisans from J&K and Nagaland to Delhi. Available from: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1812163 [Accessed 22nd October 2022]

Preetha, M. S. (2022) Tech up gradation fund scheme for textiles on the anvil. The Hindu. Available from: https://www.thehindu.com/business/tech-upgradation-fund-scheme-for-textiles-on-the-anvil/article38366467.ece [Accessed 4th August 2022].

PSG College of Technology (2016) Consultancy Work Completed. Available from: https://www.psgtech.edu/Research/Consultancy%20work%20completed.pdf [Accessed 22nd October, 2022]

PSG College of Technology (2016) PSGTECHS COE INDUTECH /Tender FIC 4. Available from: https://www.psgtech.edu/coeindutech/Tender%20FIC%204%20document%20with%20corrigendum%20%201.pdf [Accessed 22nd October 2022]

PTI (2021). India's Textile Sector needs more support to arrest shrinking market share. The Economic Times. Available from: https://economictimes.indiatimes.com/small-biz/trade/exports/insights/indias-textile-sector-needs-more-support-to-arrest-shrinking-market-share/articleshow/84629580.cms [Accessed 7th August 2022].

PTI (2022) Apparel Industry Sustainability Action (AISA) launched. Apparel Resources News. 05th July 2022. Available from: https://apparelresources.com/business-news/sustainability/apparel-industry-sustainability-action-aisa-launched/ [Accessed 22nd October, 2022]

PTI (2022) Govt. may relax key criteria to sweeten textile PLI 2.0. Financial Express. 26th September 2022. Available from: https://www.financialexpress.com/economy/govt-may-relax-key-criteria-to-sweeten-textile-pli-2-0/2690440/ [Accessed 22nd October 2022]

PTI (2022) To boost startup financing, government offers incentives to VC, PE funds. Economic Times. 07th May 2022. Available from: https://economictimes.indiatimes.com/tech/funding/to-boost-startup-financing-government-offers-incentives-to-vc-pe-funds/articleshow/91383159.cms [Accessed 22nd October 2022]

Ranga, M., and Etzkowitz, H. (2013) Triple Helix systems: An analytical framework for innovation policy and practice in the Knowledge Society. Industry and Higher Education, 27 (4), pp. 237–262. Available from: https://doi.org/10.5367/ihe.2013.0165 [Accessed 22nd October 2022]

Reischauer, G. (2018) Industry 4.0 as policy-driven discourse to institutionalise innovation systems in manufacturing. Technol. Forecast. Soc. Change, 132, pp. 26–33. Available from: https://doi.org/10.1016/J.TECHFORE.2018.02.012 [Accessed 16th October 2022]

Reserve Bank of India (RBI) (2020) RBI Bulletin March 2020. Available from: https://rbidocs.rbi.org.in/rdocs/Bulletin/PDFs/02AR_110320207BF5BBAA459047E49DADA63E3E25BD95.PDF [Accessed 15 January 2023]

R. Jiang, et. al. (2017) Predicting the future of additive manufacturing: A Delphi study on the economic and societal implications of 3-D printing for 2030. Technological Forecasting and Social Change, 117, pp. 84-97, DOI: 10.1016/j.techfore.2017.01.006 [Accessed 5th November 2022].

Roman, M., Varga, H., Cvijanovic, V. and Reid, A. (2020) Quadruple Helix models for sustainable regional innovation: Engaging and facilitating civil society participation. Economies, 8 (2), p.48

Rübmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., Harnisch, M. (2015) Industry 4.0: The future of productivity and growth in manufacturing industries, Boston Consulting Group.

Ruiz, K., Corrales, R., and Orozco, J. (2017) Main components that influence the link between Public Research Bodies and Companies. University-productive sector linkage to strengthen national innovation systems: Experience of Cuba, Mexico and Costa Rica (pp. 393–422).

Rummel, R.J. (1970) Applied Factor Analysis. Evanston: Northwestern University Press

Sanghvi, K. (2007) Challenges in weaving automation. Available from: https://www.fibre2fashion.com/industry-article/1805/challenges-in-weaving-automation [Accessed 16th October 2022]

Sarpong, D., AbdRazak, A., Alexander, E., and Meissner, D. (2017) Organizing practices of university, industry and government that facilitate (or impede) the transition to a hybrid triple helix model of innovation. Technological Forecasting and Social Change, 123, pp. 142–152. Available from: https://doi.org/10.1016/j.techfore.2015.11.032 [Accessed 16th October 2022]

Saxenian, A. (1994) Regional advantage: Culture and competition in Silicon Valley and Route 128. Harvard University Press.

Schilke O. (2014) On the contingent value of dynamic capabilities for competitive advantage: The nonlinear moderating effect of environmental dynamism. Strategic Management Journal; 35:179-203.

Sharma, A., Sharma, C., Mallick, S., and Kandpal, T. (2018) Incentives for promotion of solar industrial process heating in India: a case of cotton-based textile industry. Clean Technologies and Environmental Policy, (2018), 20, pp. 813-823, Available from : https://link.springer.com/content/pdf/10.1007/s10098-018-1499-1.pdf [Accessed 28th October 2022]

Sharma, A., Lakshmanan, R., and Nayyar, M. (2020) Technical Textiles: The Future of Textiles. Available from: https://www.investindia.gov.in/siru/technical-textiles-future-textiles [Accessed 29th October 2022]

Sharma, D. (2022) Sericulture: Importance and Potential. Just Agriculture, 2 (5), Available from: https://justagriculture.in/files/newsletter/2022/january/075.pdf [Accessed 22nd October 2022]

Shekar, K.C. and Joseph, K.J. (2022) Determinants of innovation and interactive learning in informal manufacturing enterprises in India. Science and Public Policy, 49 (3), pp. 427-440. Available from: https://doi.org/10.1093/scipol/scab089 [Accessed 22nd October 2022]

Shekar, K.C. and Paily, G. (2019) The need for an innovation survey in India. Economic & Political Weekly, 54 (38), pp. 19-22.

Sikka, M. P., Sarkar, A., and Garg, S. (2022) Artificial Intelligence (AI) in textile industry operational modernization. Research Journal of Textile and Apparel, Available from : 10.1108/RJTA-04-2021-0046 (Accessed 5th November 2022)

Silva, V. L., Kovaleski, J. L., and Pagani, R. N. (2019) Technology transfer and human capital in the industrial 4.0 scenario: A theoretical study. Future Studies Research Journal: Trends and Strategies, 11 (1), pp. 102-122.

Singhal, R. (2007) Fragmented capacities stifle growth. The Economic Times. Available from: https://economictimes.indiatimes.com/rajrishi-singhal/fragmented-capacities-stifle-growth/articleshow/2599069.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst [Accessed 6th August 2022].

Sirmon, D.G., Hitt, M.A., and Ireland, R.D. (2007) Managing Firm Resources in Dynamic Environments to Create Value: Looking inside the Black Box. Academy of Management Review, 32, pp. 273-292. Available from: http://dx.doi.org/10.5465/AMR.2007.23466005 [Accessed 20th June 2022].

SITRA (n.d.), COE Medical Textiles. Available from: Incubation Centre for Medical Textiles in India | Medical Textile Consultancy Services - SITRA, Coimbatore

Smith, K. (1996) Systems Approaches to Innovation: some Policy Issues, report from the ISE project. submitted to the Commission, December.

State Bank of India (2018) SBI Strategic Training Unit. Available from: https://sbi.co.in/web/strategic-training-unit/sbiit-hyderabad [Accessed 22nd October 2022]

Stenzel, T. (2007) The diffusion of renewable energy technology - Interactions between utility strategies and the institutional environment. Centre for Environmental Policy. Imperial College, London.

Surana, K., Singh, A., Sagar, A., (2018) Enhancing S&T Based Entrepreneurship: The role of incubators and public policy. DST Centre for Policy Research, Indian Institute of Technology, Delhi.

Tabachnick B.G., and Fidell L.S. (2007) Using multivariate statistics. Fifth Edition. Pearson Education Inc.

Tamil Nadu Infrastructure Fund Management Corporation Ltd. (n.d.) Overview of Company. Available from: TNIFMC - Tamil Nadu Infrastructure Fund [Accessed 22nd October, 2022]

Textile Value Chain (2020) Policies that led to the growth of Textile and Garment Industry. Available from: https://textilevaluechain.in/news-insights/policies-that-led-to-the-growth-of-textile-and-garment-industry-in-india/ [Accessed 10th August 2022].

Textile Value Chain (2022) Power Loom Cluster in India. Available from: https://textilevaluechain.in/in-depth-analysis/articles/textile-articles/power-loom-cluster-in-india/ [Accessed 1st November 2022].

Thomas, M. (2012) Textile printing in fabric industry going digital. The Times of India. Available from: http://timesofindia.indiatimes.com/articleshow/14286787.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst [Accessed 16th October 2022]

Tofail, Syed A.M., Koumoulos, Elias P., Bandyopadhyay, A., Bose, S., Donoghue, L., and Charitidis, C. (2018) Additive Manufacturing: scientific and technological challenges, market uptake and opportunities. Materials Today, 21 (1), pp. 23-37, Available from: https://reader.elsevier.com/reader/sd/pii/S1369702117301773?token=7023530A233E47BF375F2D32A3E137C2DC05755F64532799AABC7B087785250F6395C548350F8C232628845E9203EFD0&originRegion=eu-west-1&originCreation=20221107082031 [Accessed 6th November 2022].

Tushman, M. L. and Scanlan, T. J. (1981) Boundary spanning individuals: Their role in information transfer and their antecedents. Academy of management journal, 24 (2), pp. 289-305.

UNIDO IAP (2023) UNIDO 'Industrial Analytics Platform'. Available from: https://iap.unido.org/ [Accessed 18th January 2023]

Wang, M. K., Hwang, K. P., and Lin, S. R. (2011) An empirical study of the relationships among employee's perceptions of HR practice, human capital, and department performance: A case of AT & T Subordinate telecoms company in Taiwan. Expert Systems with Applications, 38 (4), pp. 3777-3783.

Weber, K. M., and Truffer, B. (2017) Moving innovation systems research to the next level: Towards an integrative agenda. Oxford Review of Economic Policy, 33 (1), pp. 101–121. Available from: https://doi.org/10.1093/oxrep/grx002 [Accessed 22nd October 2022]

Webster, A. (2000) Innovation and Knowledge Dynamics – SATSU Working paper N16 2000. Soziale Technik 4 (99), 12-1.

Whelan, E., Teigland, R., Donnellan, B., and Golden, W. (2010) How internet technologies impact information flows in R&D: Reconsidering the technological gatekeeper. R&D Management, 40 (4), pp. 400-413.

Williamson, O.E. (1969) Allocative efficiency and the limits of antitrust. American Economic Review, American Economic Association, 59(2), 105-18.

Williamson, O.E. (1971) The vertical integration of production: Market failure considerations. American Economic Review, American Economic Association, 61(2), 112- 23.

Williamson, O.E. (1973) Markets and hierarchies: Some elementary considerations. American Economic Review, American Economic Association, 63(2), 316-25.

Winskel, M. & Moran, B. (2008) Innovation theory and low carbon innovation: Innovation processes and innovations systems. Edinburgh University.

Winter, S. G. (1987) Knowledge and competence as strategic assets. In: Teece D. (ed.) The competitive challenge-strategies for industrial innovation and renewal. Ballinger. (pp. 159–184).

Woolthuis, R.K., Lankhuizen, M. and Gilsing, V. (2005) A system failure framework for innovation policy design. Technovation, 25 (6), pp.609-619.

Zhou, Y., Miao, Z., and Urban, F. (2020) China's leadership in large hydropower. Industrial and Corporate Change, 29 (5), pp. 1319-1343.

Zook, M. A. (2004) The knowledge brokers: Venture capitalists, tacit knowledge and regional development. International Journal of Urban and Regional Research, 28 (3), pp. 621–641. Available from: https://doi.org/10.1111/j.0309-1317.2004.0054 [Accessed 22nd October 2022]

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 13	**Manufacture of textiles**
Group 131	Spinning, weaving, and finishing of textiles
Group 139	Manufacture of other textiles
Division 14	**Manufacture of wearing apparel**
Group 141	Manufacture of wearing apparel, except fur apparel
Group 142	Manufacture of articles of fur
Group 143	Manufacture of knitted and crocheted apparel

http://www.nstmis-dst.org/NMIS/index.html

Scan for all reports

Vienna International Centre
Wagramerstr. 5, P.O. Box 300,
A-1400 Vienna, Austria

+43 1 260-0

unido@unido.org

www.unido.org

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION