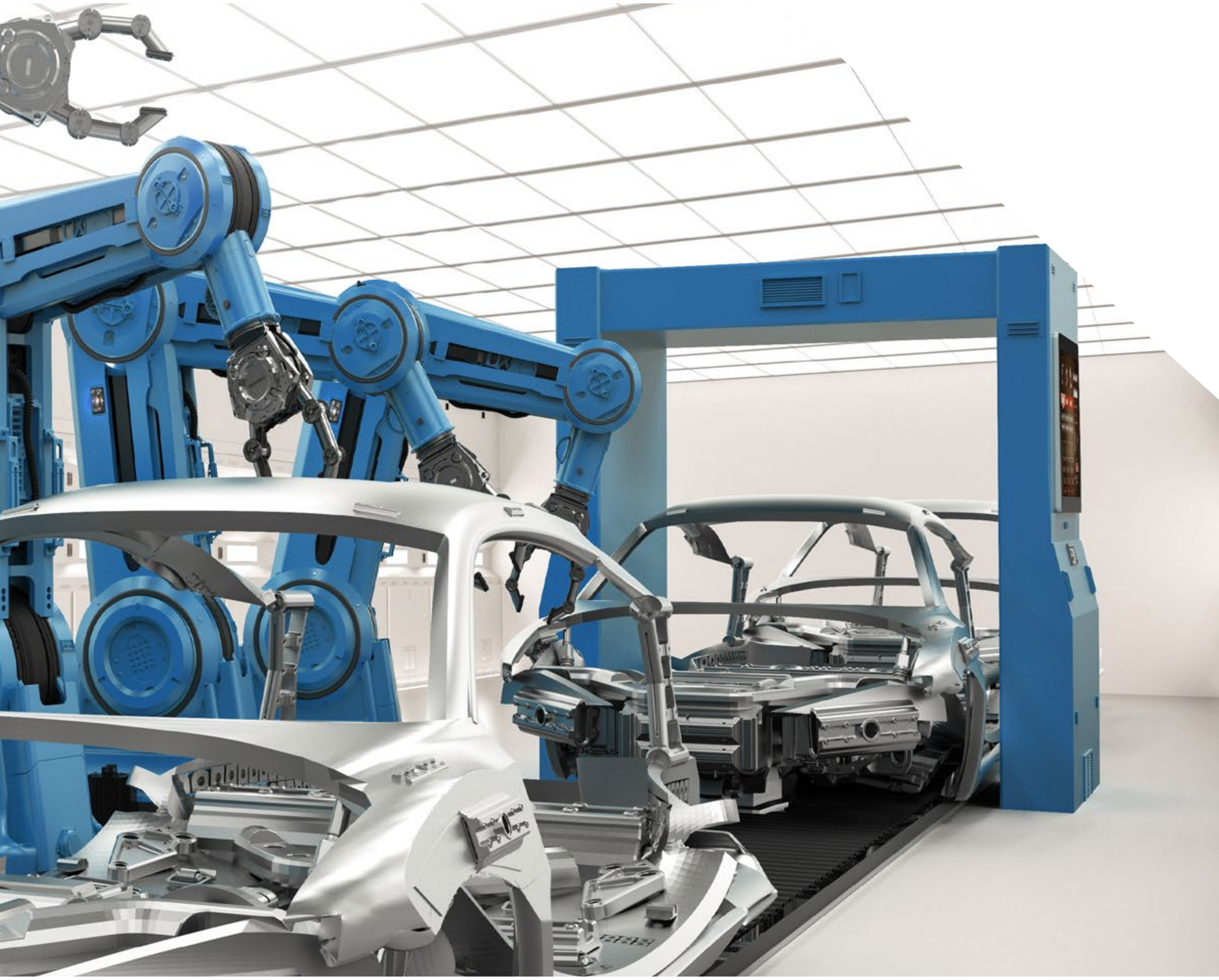
UNIDO-ACMA-DHI
Survey Report

Indian Automotive Sectorial System of Innovation

Measurement, Analysis, & Policy Recommendations



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INDIAN AUTOMOTIVE SECTORIAL SYSTEM OF INNOVATION - MEASUREMENT, ANALYSIS AND POLICY RECOMMENDATIONS

UNIDO-ACMA-MHI Survey Report

Vienna, Austria
November 2022

Department of Heavy Industry,
Government of India

UNIDO

ACMA

Acknowledgements

The IASSI Survey and report would not have been possible without the close collaboration of key personnel from the Government of India GoI (GoI), Ministry of Heavy Industries (MHI), namely: Mr. Amit Mehta, Joint Secretary, MHI; and Mr. Marco Kamiya, Chief, Division of Digital Transformation and AI Strategies (TCS/DAS), United Nations Industrial Development Organization (UNIDO). Profound expressions of appreciation and special gratitude are extended to Mr. Vinnie Mehta, the Director-General of the Automotive Component Manufacturers Association of India (ACMA), for making ample resources available for the execution of the survey and actively participating in the project. Special thanks are extended to Dr. Reji Mathai, Director of the Automotive Research Association of India (ARAI); Mr. Vikram Tandon, Deputy General Manager, ARAI; Ramachandran Sundararajan and Nampuraja Enose from Infosys; and Professor Dr. Saon Ray, at the Indian Council for Research on International Economic Relations (ICRIER) for their support in the peer review of the report.

The IASSI Survey and the data analysis and results presented in this report have been performed, analysed, and authored by Dr. Ritin Koria, Project Specialist for Innovation, UNIDO, and Ms. Christi Thomas, Project Associate, UNIDO.

The following enumerators provided excellent and invaluable support in the field, in India, for operationalising the survey and data acquisition: Mr. Vikhyat Maheshwari, Ms. Arushi Jain, Ms. Navdeep Kaur, and Mr. Keerthi Vikram Venkatesan from BML Munjal University (BMU); Mr. Digvijay Patil, Mr. Suneesh Mukku and Mr. Chandrakant K. from Tata Institute of Social Sciences (TISS); Mr. Siddharth Baxi, Mr. Dharmik Vasani from Nirma University; Aishwarya Phagiwala from JECRC University; Ms. Levia Singla and Ms. Sakshi Sharma from Goswami Ganesh Dutta Sanatan Dharma College; Pratik Dake from Dr. Babasaheb Ambedkar Marathwada University (BAMU); Mr. Gaurav Patil, Mr. Parimal Rainchwar and Mr. Swanand Jagtap from Savitribai Phule Pune University (SPPU).

Ms. Lauren Cooke is thanked for editorial work. Appreciation is also extended to Mr. Tomoyoshi Koume, Industrial Development Officer, UNIDO, for overseeing the overall project, and Ms. Rekha Jain, National Programme Manager, UNIDO and Ms. Sirjjan Preet, Regional Project Coordinator, UNIDO in India, whose efficient administrative and logistical support made the project execution all the more effective.

ACMA 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

Over the last decades, India's economic growth has often been explained as a services-driven phenomenon. However, some manufacturing sectors have played an essential role in this economic growth, and the automotive industry is prominent and will continue to play a central role in India's aspiration to become a USD 5 trillion economy by 2025. The growth of the automotive industry lies in the utilisation of the Fourth Industrial Revolution (4IR) technologies, innovation, knowledge production, and digital transformation. The growing capabilities and rising affordability of the 4IR digital technologies are opening new avenues of opportunity for advancing economic competitiveness, creating shared prosperity, safeguarding the environment, and strengthening knowledge and institutions.

Consequently, the application of coherent and effective policy represents the ability of an economy to enhance its competitiveness and economic growth, particularly in the broader context of the global knowledge-based economy. Innovation and digital transformation are not only a source of quality employment and the backbone of any knowledge-based economy; They also enable business support, entrepreneurship, and MSME development.

With an increasing importance on knowledge as a critical economic driver, better management of knowledge resources is necessary, and the systematic organisation of tacit and codified knowledge is particularly crucial. A System of Innovation (SI) represents the strength and quality of the systematically organised interactions and linkages between government, knowledge-based institutions, industry, intermediaries (institutions supporting technical change and industry associations), and arbitrageurs (venture capital, angel investors, and financial institutions). The measurement, visualisation, and understanding of the dynamics of an innovation system are crucial to formulating evidence-based policy for the effective use of resources.

UNIDO acknowledges the importance of evidence in optimally deploying policy instruments and targeting available resources (economic incentives and institutions) so that the Indian automotive sector can achieve a competitive advantage. The development of a well-functioning SI is needed to attain competitive advantage, working as a driver for long-term socio-economic development.

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 "Indian Automotive Sectorial System of Innovation (IASSI) – Measurement, Analysis, and Recommendations" maps and analyses the challenges, potential, and opportunities arising from the innovation system. It is a source of policy insight for supporting the Government of India to elaborate a coherent, evidence-based industrial policy that articulates the role of science, technology, and innovation throughout the economy.

The chapters in this report are the result of UNIDO's services in capacity-building, policy analysis, and empirical research on the Indian automotive 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, policies, and management of policy actions to achieve national targets and goals effectively.

Mr. Marco Kamiya

Chief, Division of Digital Transformation & AI Strategies (DAS) UNIDO

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Acronyms

4IR	Fourth Industrial Revolution
AAT	Advanced Automotive Technology
ACC	Advanced Cell Chemistry
ACMA	Automotive Component Manufacturers Association of India
ADP	Advanced Digital Production
AGV	Automated Guided Vehicles
AI	Artificial Intelligence
AIF	Alternative Investment Fund
AIM	Atal Innovation Mission
AIPAC	Alternative Investment Policy Advisory Committee
AIS	Automotive Industry Standards
AMP	Automotive Mission Plan
ANIC	Atal New India Challenge
APO	Asian Productivity Organization
ARAI	Automotive Research Association of India
ARB	Arbitrageurs
ASDC	Automotive Skills Development Council
ASI	Annual Survey of Industries
ASMC	Automotive Suppliers Manufacturing Centre
BAMU	Babasaheb Ambedkar Marathwada University
BIS	Bureau of Indian Standards
BMU	BML Munjal University
BNVSAP	Bharat New Vehicle Safety Assessment Programme
BS IV/V/VI	Bharat Stage IV/V/VI
BTS	Bartlett's Test of Sphericity
CEO	Chief Executive Officer
CII	Confederation of Indian Industry
CMIE	Centre for Monitoring Indian Economy
CMVR-TSC	Central Motor Vehicle Rules - Technical Standing Committee
CNC	Computerised Numerical Control
COE	Centre of Excellence
CPS	Cyber-Physical Systems
CRC	Collaborative Research Centres
CVCFL	Canbank Venture Capital Fund Ltd.
DASI	Data Acquisition Survey Instrument
DASI-V4	Data Acquisition Survey Instrument Version 4

DCAAI	Development Council for Automobiles and Allied Industries
DISK	Data Information Statistics and Knowledge
DMIC	Delhi Mumbai Industrial Corridor
DPIIT	Department for Promotion of Industry and Internal Trade
DST	Department of Science & Technology
DTI	Digitalization, Technology and Innovation
DTSi	Digital Twin Spark Ignition
EVs	Electric Vehicles
FAIR	Findable, Accessible, Interoperable and Reusable
FAME	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles
FDI	Foreign Direct Investment
FIs	Financial Institutions
FOSS	Free Open Source Software
FTP	Foreign Trade Policy
FY	Financial Year
GARC	Global Automotive Research Centre (GARC)
GDP	Gross Domestic Product
GFR	General Financial Rules
GII	Global Innovation Index
GoI	Government of India
GOV	Government
GST	Goods and Services Tax
GTR	Global Technical Regulations
GVCs	Global Value Chains
HERC	Higher Education Research Centres
HMI	Human-Machine Interaction
IAP	Indian Automotive Products
IASSI	Indian Automotive Sectorial System of Innovation
IBEF	India Brand Equity Foundation
ICAT	International Centre for Automotive Technology
ICE	Internal Combustion Engines
ICRIER	Indian Council for Research on International Economic Relations
ICT	Information and Communications Technology
IND	Industry
INDSTA	Indian Science and Technology Archive of Research
INT	Intermediaries
IOM	International Organization for Migration
IoT	Internet of Things
IP	Intellectual Property
IPR	Intellectual Property Rights

IRRD	Industry Relevant R&D
ISTC	Institutions Supporting Technical Change
IT	Information Technology
KBI	Knowledge-Based Institution
KIADB	Karnataka Industrial Areas Development Board
KMO	Kaiser-Meyer-Olkin
LMIS	Labour Market Information System
MEIS	Merchandise Exports from India Scheme
MEITY	Ministry of Electronics and Information Technology
MHI	Ministry of Heavy Industries
ML	Machine Learning
MNRE	Ministry of New and Renewable Energy
MoRTH	Ministry of Road Transport and Highways
MoUD	Ministry of Urban Development
MPNG	Ministry of Petroleum and Natural Gas
MSME	Micro, Small and Medium Enterprises
NAC	National Automotive Council
NAP	National Automotive Policy
NASSCOM	National Association of Software and Service Companies
NATRAX	National Automotive Test Tracks
NATRiP	National Automotive Testing and R&D Infrastructure Project
NBEM	National Board for Electric Mobility
NCEM	National Council for Electric Mobility
NCR	National Capital Region
NEP	National Education Policy
NIAIMIT	National Institute of Automotive Inspection, Maintenance & Training
NMIZs	National Investment and Manufacturing Zones
NLP	National Logistics Policy
NMEMP	National Mission for Electric Mobility Plan
NPBF	National Policy on Biofuels
NSDC	National Skill Development Corporation
NUTP	National Urban Transport Policy
NVH	Noise Harshness and Vibration
ODM	Original Design Manufacturing
OECD	Organisation for Economic Co-Operation and Development
OEM	Original Equipment Manufacturer
PAL	Premier Auto Limited
PIB	Press Information Bureau
PISC	Project Implementation and Sanctioning Committee
PLI	Production Linked Incentive

PMGSY	Pradhan Mantri Gram Sadak Yojana
PMP	Phased Manufacturing Programme
PTI	Press Trust of India
QPs	Qualification Packs
R&D	Research and Development
RIs	Research Institutes
RoDTEP	Remission of Duties and Taxes on Exported Products
SAIL	Steel Authority of India Limited
SAMARTH	Smart Advanced Manufacturing and Rapid Transformation Hub
SBICAP	State Bank of India Capital Markets Limited
SEBI	Securities and Exchange Board of India
SERB	Science and Engineering Research Board
SEZ	Special Economic Zone
SI	System of Innovation
SIAM	Society of Indian Automobile Manufacturers
SMEs	Small and Medium Enterprises
SPPU	Savitribai Phule Pune University
SPV	Special Purpose Vehicle
SSI	Sectorial System of Innovation
STEM	Science, Technology, Engineering and Mathematics
STI	Science, Technology and Innovation
STIP	Science and Technology Innovation Policy
SVCL	SIDBI Venture Capital Limited
TH	Triple Helix
TIFAC	Technology Information Forecasting and Assessment Council
TISS	Tata Institute of Social Sciences
TLCs	Teaching-Learning Centres
TPEM	Technology Platform for Electric Mobility
TVE	Total Variance Explained
UNECE	United Nations Economic Commission for Europe
UNIDO	United Nations Industrial Development Organization
VC	Venture Capital
VDRE	Vehicle Research & Development Establishment
WIPO	World Intellectual Property Organization
WP	Working Party
WTO	World Trade Organization

Executive Summary

This report, titled the "Indian Automotive Sectorial System of Innovation (IASSI) – Measurement, Analysis, and Policy Recommendations" surveys and depicts the essential and systemic features of the landscape of innovation and innovativeness in the automotive sector in India. The report has been compiled for the benefit of the Government of India (GoI) policymakers. This initiative is a positive first step towards a coherent policy delivery mechanism and a long-term policy monitoring and management capability for the sector.

Although there are many significant challenges identified, the policy analysis, implications arising from the analyses, and the policy recommendations to address these implications provide an unprecedented menu of evidence-based policy choices to address the challenges. The approach outlined in this report is comprehensive and holistic for mapping and measuring the Indian Automotive Sectorial System of Innovation (IASSI). The value addition provided enables accurate visualisation of the connectivity between the core actors of the IASSI, the significant barriers to innovation and innovativeness, and the relative success of extant policies in overcoming these barriers. After all, it is not a matter of the number of assets a country has with respect to innovation and innovativeness, but rather how well and coherently they are connected and managed.

In presenting the results for the benefit of policymakers, and the essential and systemic characteristics of the landscape of innovation and innovativeness, this report represents a landmark in evidence-based policymaking in the automotive sector in India. It is the result of project execution under the aegis of the Department of Heavy Industries (Ministry of Heavy Industries, GoI), in concert with the Automotive Component Manufacturers Association (ACMA).

All results and reporting have undergone a rigorous independent review by representatives of the Automotive Research Association of India (ARAI) and the Indian Council for Research on International Economic Relations (ICRIER).

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

Firstly, there is the need to foster linkages between crucial actors of the IASSI, particularly for the use and application of joint research, skills orientation and development, and access to finance. Secondly, the analysis highlights that relationships between actors in the IASSI are imbalanced, hindering the flow of knowledge and information crucial to the innovation process. The imbalanced relationships link to the third finding that the most significant latent factor barriers to innovation for the system are the lack of readiness for Industry 4.0, undynamic markets and directives, and insufficient policy and regulatory support. The results show limited potential to innovate in the automotive sector and compete effectively in global markets.

With respect to policy success, policy instruments are analysed in terms of supply-side measures (services and financial) and demand-side measures. The study results indicate that 'Labour mobility laws and incentives,' 'Business support organizations' and 'Govt procurement' are the policy instruments that need to be re-oriented through the lens of the IASSI to meet the development objectives of the sector.

Conversely, different actors signal the success of varying policies. Industry respondents view demand-side policies, namely, 'Regulation' and 'Tax breaks,' as most successful. KBI respondents view 'Research grants,' 'ICT access,' and 'Focused skills development initiatives' as most successful. Intermediaries such as 'Standards setting,' 'Regulation', 'ICT access' and ‘Focused skills development initiatives’ are viewed as most successful, while ‘Research grants,’ ‘Standards setting,’ and ‘Spatial policies’ are viewed as successful by arbitrageur respondents. However, the most prominent of these are the demand-side measures, ‘Regulation’ and ‘Tax breaks,’ as well as the supply-side services ‘ICT access’ and ‘Focused skills development initiatives.’

The diverse responses highlight that policymakers can disseminate certain best practices with respect to policy craft in the automotive sector to address the bottlenecks mentioned above.

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.

Policymakers should not use a one-size-fits-all approach. Regional nuances should inform the policy process. This is elucidated by the different barriers observed in the clusters in the north and south of India, namely, undynamic markets, inflexibility and poor human capital retention, respectively.

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. Research institutions are weakened by the absent nexus of the knowledge-base and industry. The lack of positive externalities magnifies the negative impact of the absent relationships relevant to innovation in the sector. The remoteness of actors causes them to be relatively independent of the policy-making process, especially in terms of wielding influence in configuring and calibrating policy to exploit knowledge and intermediating the flows of technical know-how. The present public infrastructure needs to be strengthened to build and bolster linkages. What is required is a widely accepted conducive environment in which organizational rigidities are removed.

The IASSI Report recognises the value of comprehensive survey instrumentation and the critical importance of mapping and measurement to guide the discussion for evidence-based policy craft and management. The reapplication of the methodology of mapping and measuring the IASSI in two to three years to ascertain the effects of policy choices, implementation, resource application, and hence innovation and innovativeness in the Indian economy, is strongly advised.

In presenting the IASSI analysis, implications and recommendations, the sovereignty of the GoI is fully respected. The observations, implications, and recommendations that emerge from the analysis need to be considered holistically and fully. The final selection of recommendations and the resources to be applied in implementing policy on innovation and innovativeness remain matters of sovereign choice by, and priority of, the GoI.

1.

Introduction

Introduction

The IASSI Survey was launched in July 2020 as part of the "UNIDO-ACMA-MHI Partnership Programme" (Phase II), a joint initiative of the United Nations Industrial Development Organization (UNIDO), the Automotive Component Manufacturers Association (ACMA), and the Ministry of Heavy Industries (MHI), Government of India (GoI). It emphasises the roles of knowledge, science, technology, and innovation (STI) and the linkages between system actors in the IASSI.

The primary purpose of this report is to: inform policymakers with evidence on the national debate on innovation for the automotive sector; better enable the GoI to consider strategic, operational, and tactical policy choices, and facilitate better deployment of the available resources in a prioritised and sequential manner, either by concentrating on reinforcing strengths or overcoming weaknesses.

Consequently, the report is analytically intense, drawing attention to strengths, weaknesses, fragility and points of vulnerability and liability in the IASSI. This attention is expressed without value judgement, in full respect of the sovereignty of the GoI.

Given the complexity and emergent characteristics of the IASSI, the report achieves this purpose by:

i. providing a statistically significant set of tools, resources, and metrics with which policy management can be mapped and measured through evidence-based data and analysis;
ii. explaining the institutional and structural challenges faced in policy management for the IASSI;
iii. setting out key ideas, insights, research and evidence from the survey; and
iv. delineating key principles for the GoI policymakers and the supporting policy community in India.

These are summarised as analysis, policy implications, and policy recommendations.

Regarding the management of the IASSI, policymakers confront four significant issues:

i. the need to comprehend the increasing pressures of decision-making better;
ii. the dynamic tension between evidence, heuristics, practice, and theoretical considerations;
iii. the lack of data availability; and
iv. the need for evidence-based pragmatic approaches that provide insights for decision-making.

The report portrays patterns, dynamics, the interconnectedness of actors, and their collective behaviour within the IASSI. In digesting the report, policymakers need to take into account the following key ideas:

i. the IASSI is characterised by a complex system of elements that are differentially interdependent and interconnected by multiple feedback mechanisms, and that system-wide behaviour emerges from accumulated interactions among the parts;
ii. in complex systems (Allen., 2000), processes of change are highly sensitive to conditions and can shift dramatically with non-linear tipping points (points of policy leverage);
iii. as a complex, ultimately human, system, the IASSI is operated by 'adaptive agents' that act to maximise their interests and managerial utility, who network, react to and influence other actors in the system. Enhancing these networks' adaptive responses, capacities and capabilities through policy levers is essential to strengthening resilience, innovativeness, and innovation.

Consequently, the following seven principles guide the policy analysis, implications, and recommendations:

i. one cannot manage what is not measured and what gets measured gets done;
ii. understanding the systemic nature of the IASSI;
iii. involving those actors that matter the most in decisions crucial to the effectiveness and efficiency of the IASSI;
iv. avoiding 'one-size-fits-all strategies' and embracing multiple policy instruments;
v. establishing real-time and longitudinal analysis and learning as key to operational effectiveness;
vi. openness to the adaptation of efforts to local conditions;

vii. framing the policy management of the IASSI as a dynamic network involving a multilateral system of actors.

With these principles, a more innovative, relevant, and appropriate approach to the policy management of the IASSI is possible.

UNIDO-ACMA-MHI Partnership Programme (Phase II)

This programme is an extension of the established UNIDO-ACMA methodology developed in Phase I (2014-2017).

The overall objective of this programme is to improve productivity and innovation of the automotive sector through facilitating digital transformation and increasing the adoption of Industry 4.0. Through a strengthened system of innovation, the bolstering of linkages between system actors, and implementing relevant technologies, small component manufacturers can better succeed as preferred suppliers to national and international tier-one manufacturers and Original Equipment Manufacturers (OEMs). This project aims to increase the scope and coverage of the UNIDO-ACMA Partnership Programme and provide valuable services to SMEs to achieve the following inter-related outputs:

- Increase the availability and applicability of productivity improvement and innovation enhancement methods and tools and capacity of ACMA counsellors for automotive component manufacturers.
- Enhance the productivity of selected supplier companies by adopting continuous improvement techniques utilising focused counselling and e-learning.
- Strengthen the automotive sector ecosystem for increased innovation through technology adoption and digital transformation.
- Improve market access for selected Indian automotive component manufacturers through supply chain development.
- Support in assessing the technology needs and implementation of relevant technology components and tools.
- Support mechanisms for SMEs to make sure that they are not left behind in the larger technology revolution underway in the industry (Industry 4.0).

In light of the above, the project would significantly contribute to fulfilling UNIDO's mandate of inclusive and sustainable industrial development. These activities aim to achieve SDG 9 - 'to build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.'

Structure of the Report

This report is structured as follows: The 'Theoretical Underpinnings' chapter offers a literature review on the SSI and the Triple Helix. It emphasises the genesis and evolution of the SSI approach and the role and impact of government-university-industry relations for fostering an economy's innovation capacities. In addition to these established models of analysis, we present UNIDO's approach – the Triple Helix Type IV which stresses the role of arbitrageurs; intermediaries such as industry associations and institutions supporting technical change (ISTCs), and the importance of Industry 4.0 adoption and digital transformation through a well-established ICT infrastructure for a well-functioning SSI.

The 'Methodology' chapter presents the methodological approach that was used in undertaking the IASSI Survey. This chapter is followed by an 'Overview of India's Automotive Sector', which sets the scene for an in-depth analysis of the SSI, taking into account the positioning of Indian firms within global value chains (GVCs), state-of-the-art technology and global challenges such as the COVID-19 pandemic. This is followed by the chapter on 'Policy Review', which articulates national policy priorities regarding science, technology and innovation (STI), automotive sector policies and innovation policies with respect to industry, information and communication technology (ICT) and education.

The 'Results and Analysis' chapter is the core of this report and provides an empirical analysis of the IASSI Survey. It depicts the inter- and intra-actor linkages of the IASSI and offers an evaluation of the sector's innovativeness, barriers to innovation and the perceived success of policy instruments. This culminates in a set of unique evidence-based policy recommendations for the Government of India (GoI) in order to foster inclusive and sustainable industrial growth, innovation, and entrepreneurship in the automotive sector.

2.

Theoretical Underpinnings

Theoretical Underpinnings

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 if it does not wish to find itself on the downside of the cross-country income distribution. 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, 2016a; Chaminade et al., 2018). More importantly, from a development perspective, 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). This chapter presents the theoretical underpinnings for the approach used in mapping and measuring the IASSI. 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 interactions as well as its extension.

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, 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 (Kieft et al., 2017) 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).

Different types of innovation systems have emerged since the identification of the concept of innovation systems such as 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 & Malerba, 1997) and technological systems (e.g. Carlsson & Stankiewicz, 1991), also known as a technological innovation system (Bergek et al., 2008; Hekkert et al., 2007).

Geographical factors define national and regional innovation systems, whereas sectoral and technological innovation systems are defined by the knowledge base that supports a particular sector or technology (Carlsson, 2016). In the sectorial 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, such 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 flow 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, the approaches of 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 flow, 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.

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).

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).

Sectorial System of Innovation (SSI) Approach

Malerba (2002) defines sectorial systems of innovation 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 on the sector rather than on any particular geography. The three main SSI elements are typically distinguished as: a) knowledge and technological domains; b) actors and networks; and c) institutions (Malerba and Adams, 2019). Knowledge, which plays a central role in the concept, is precise at the firm level since it does not spread automatically and freely between firms (Foray, 2004) but must be absorbed by firms through the opportunities they have accumulated over time (Cohen and Levinthal, 1990). 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. Actors are individuals or/and 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).

The Triple Helix Model

The Triple Helix is effective in understanding the dynamics of innovation at the sectoral, 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, 2003b, 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, p..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, p.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, p.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, p.13).

However, in TH-Type III, the three actors assume each other's roles in the institutional spheres as well as the performance of their traditional functions. With the emergence of TH-Type III, a complex network of organizational ties has developed, both formal and informal, among the overlapping spheres of operations. The transformation of universities is of 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 the 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, p.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, p. 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, e.g. 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).

In the context of its use, 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.

Framework of Analysis

Our framework for analysis of the IASSI is grounded in the literature, but it extends the traditional model in two main ways and is referred to as Triple Helix Type IV. The TH-Type IV has the additional features of arbitrageurs and intermediary organizations (industry associations and institutions supporting technical change), as well as diffused ICT in the context of the 4IR.

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[1 2] fulfil this requirement through the provision of links, knowledge sources and even technical knowledge so that firms can improve performance in terms of their survival rate as well as accelerate and increase the effectiveness of their innovation processes (Zook, 2003; Hargadon, 1998; 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, p.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, p.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.

Intermediary organizations are pertinent in facilitating the flow of knowledge, technology and skills among the actors of the system of innovation. 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).

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 sponsoring role at policy level by channelling resources to industry; brokering role at strategic level by linking Triple Helix actors; and boundary spanning role at operational level by providing services that facilitate knowledge circulation".

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 to 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).

Table 1 below shows various types of intermediary organizations by the function they perform and the sector in which they belong. These functions span across the innovation value chain, namely: knowledge generation and transfer; technology development, acquisition and transfer; product development; testing service; commercialisation; and business development.

1 There is a varying topology for venture capital: University venture capital seeks a "balance between transferring technological innovations produced within the university to existing firms, on the one hand, and spinning them out on the other" (Etzkowitz, 2008, p.130); Corporate venture capital "seeks to capitalize knowledge that is not directly relevant to a firms core competency" (Etzkowitz, 2008, p.131); Foundation venture capital "Is at a very early stage and relatively little is known about its operation"(Etzkowitz, 2008, p.132); Community development venture capital supports firm formation in low-growth and slow-growth industries in poor communities and urban areas; and, angel investors and syndicates fill the gap in 'early stage investment' that is left open by venture capital transition to later stage investments.

2 "Each type of venture capital corrects another's deficiency. Thus, public venture capital focuses on the creation of new industries and jobs, seeking long-term economic growth. Public venture capital can maintain a focus on early-stage investments, especially in societies where the government is restrained from acting too closely to the market. … University venture capital can take a long-term perspective and is able to operate at the early seed stage. Foundation venture capital, with resources guaranteed by an independent legal structure, not subject to other organizational priorities, is the purest public venture capital instrument, able to act on the early stage and in the downturn" (Etzkowitz, 2008, pg.136).

TABLE 1: Intermediary Organizations by Function and Sector

Function	University	Government	Business
Technology Development	University-enterprise joint research centre Science park	Technology Information Forecasting and Assessment Council (TIFAC)	ACMA SIAM ARAI
Technology Transfer	Science park University-enterprise joint research centre University-owned enterprise centre	Technology Information Forecasting and Assessment Council (TIFAC) Global Innovation & Technology Alliance (GITA)	ACMA SIAM ARAI
Technology Acquisition		Global Innovation & Technology Alliance (GITA)	
R&D		Auto Cluster Development and Research Institute	Auto Cluster Development and Research Institute
Knowledge Transfer	Living labs	National Productivity Council Global Innovation & Technology Alliance (GITA)	ACMA SIAM ARAI
IP Protection	Science park	Patent offices	
Infrastructure Development		Ministry of Heavy Industries	ACMA SIAM ARAI
Product Development		National Research & Development Corporation	
Human Capital Development	University-enterprise joint research centre	Automotive Skill Development Council (ASDC) Indo German Tool Room, Aurangabad National Institute For Automotive Inspection Maintenance & Training (NIAIMT)	ACMA SIAM ARAI
Business Development	Science park Incubator Industrial park	National Engineering Research Centre Incubator Industrial park	Incubator Industrial park
Funding	University-enterprise joint research centre	Ministry of Heavy Industries Technology Acquisition and Development Fund (DIPP) Department of Scientific and Industrial Research	ACMA SIAM ARAI
Fund Raising		Ministry of Heavy Industries Banks	Venture capital Angel investors ACMA SIAM ARAI
Agenda Setting		Ministry of Heavy Industries NITI Aayog	ACMA SIAM ARAI
Testing & Certification Services	University-enterprise joint research centre	National Automotive Test Tracks (NATRAX) Bureau of Indian Standards (BIS) National Accreditation Board for Certification Bodies (NABCB) BSCIC Certifications Pvt. Ltd. National Institute for Automotive Inspection Maintenance & Training (NIAIMT)	ARAI

Source: Revised from 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 ICTs, 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 a firm's 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.

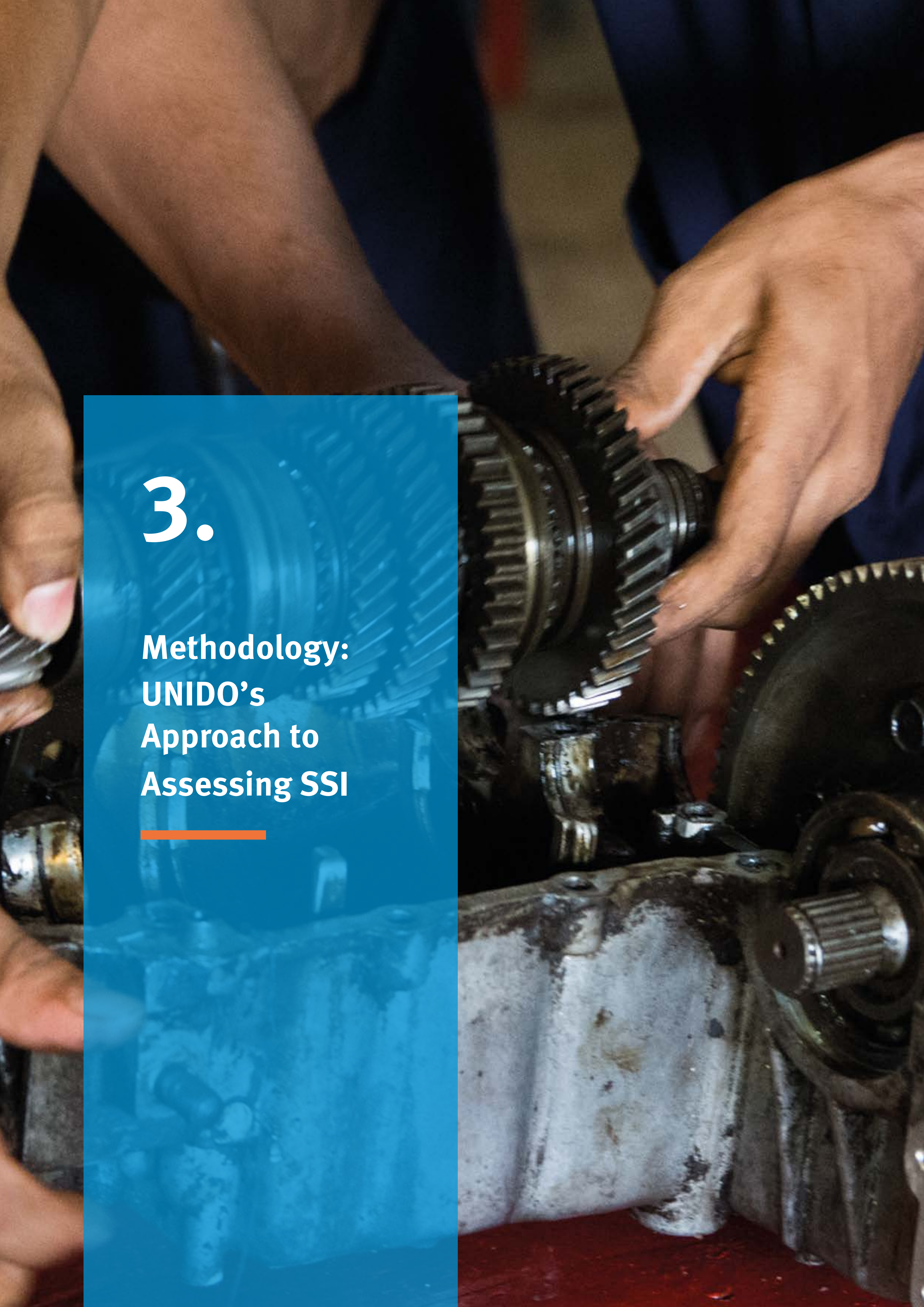
Universities have a great role to play to make the 4IR a reality, particularly through fostering the development of future skills as well as acting as testbeds for new technologies. The role of the government in the context of the 4IR is to facilitate the adoption of emerging technologies through support 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 USD 600 million in 2014 to USD 2.3 billion in 2016, representing a 40% CAGR (Deloitte, 2018b).

However, venture capitalists need to be mindful of conservative and risk-averse investment strategies that fail to consider a broad range of promising investments that are too 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 IASSI 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.

Methodology: UNIDO's Approach to Assessing SSI

Methodology: UNIDO's Approach to Assessing SSI

The IASSI Survey has been executed in the light of the fact that a holistic view of the SSI is indispensable to the efficacious execution of policy on innovation and innovativeness in the automotive sector.

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). The first category, 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 computerised 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 it is clear that the method choice is complex and based on a delicate balance between the quality of the data acquired, time and costs.

Alternative approaches to data collection exist, namely: mail surveys, face-to-face interviews and telephone interviews. 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., p.8); and v) the emergence of the COVID 19 pandemic restrictions during the implementation phase of the project which limited face-to-face interaction.

Sample Selection

As per the 'Theoretical Underpinnings' chapter, the IASSI Survey focuses on five core actor groups, namely: government (GOV), knowledge-based institutions (KBI); industry (IND); arbitrageurs (ARB); and intermediaries (INT). The composition of the actors is as follows: 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 automotive sector. The actor group KBIs, constitute 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). The industrial community is represented by the CEOs of firms from the automotive sector as per the 2019 member lists of the Automotive Component Manufacturers Association of India (ACMA), Society of Indian Automobile Manufacturers (SIAM) and Automotive Research Association of India (ARAI). Intermediaries are represented by the senior management of Institutions Supporting Technical Change (ISTC) and industry associations. Finally, arbitrageurs are composed of senior management from financial institutions (FI), angel investors and venture capitalists. A convenient sample was chosen for each actor category and contact details were verified through the Annual Survey of Industries (ASI) and the Centre for Monitoring Indian Economy (CMIE) databases.

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:

1) Selection of enumerators and retention
Given the highly technical nature of the information collected it is imperative that the selected enumerators were able to:

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

Enumerators were trained on systems of innovation, technical aspects related to the automotive sector and data collection techniques with the LimeSurvey© interface. In order to ensure data quality, Limesurvey© 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.

The Data Acquisition Survey Instrument (DASI)

The Data Acquisition Survey Instrument (DASI) for the IASSI Survey was created using an iterative multi-step process, and currently stands at its fourth iteration. The provenance of the earlier iterations of the tool can be found in 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.

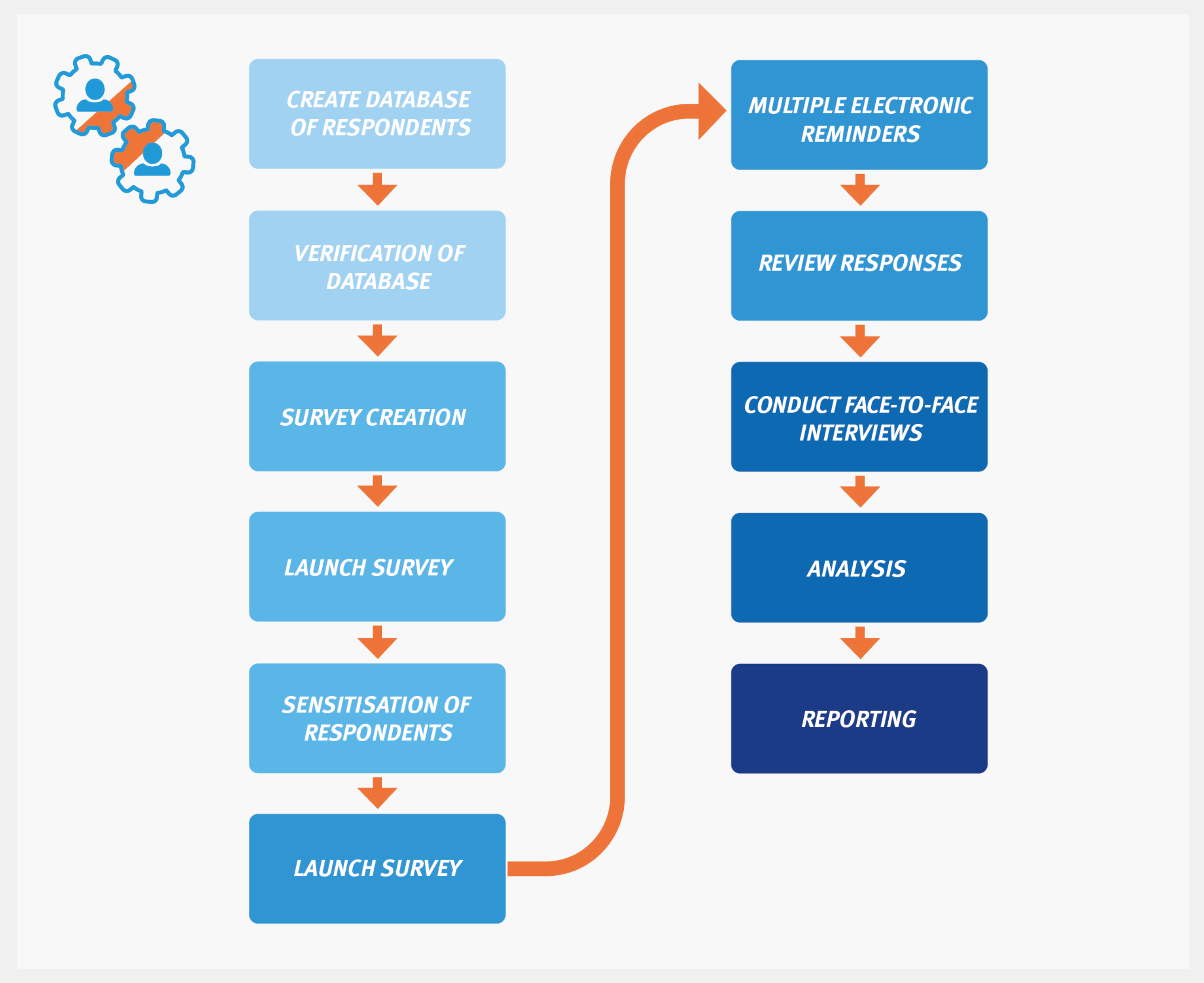
Survey Operationalisation

The launch of the survey was accomplished by using a combination of both the free open source software (FOSS) tool LimeSurvey© as well as where possible, face-to-face interviews. The LimeSurvey© tool is an advanced online survey system. The outputs from the verification protocol were uploaded into the LimeSurvey© 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 IASSI 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 LimeSurvey© 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 LimeSurvey© 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. After a period of 6 months, the survey responses were analysed with the planned statistical analysis in mind. Figure 1 shows the steps associated with the data collection process

Figure 1: Operational Methodology



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 sectoral 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 automotive 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.

4. Overview of India's Automotive Sector

Overview of India's Automotive Sector

The automotive industry in India is well-established and currently valued at USD 18 billion. It is expected to reach USD 300 billion by 2026. In 2020, India produced 26.36 million vehicles in the financial year. The sector contributes to 7.1% of India's GDP and almost 50% of manufacturing GDP, while employing around 32 million people directly and indirectly (Invest India, 2021). This industry is perhaps the only large sector wherein a very high degree of local value addition has been achieved and where India is globally competitive. The growth of the automotive industry will be critical in realising the government's objective of increasing the contribution of manufacturing to the national GDP from the current level of 16% to 25% as framed by the "Make in India" initiative. It is important to note that integrating the principles of Industry 4.0 is essential to achieving this target.

In terms of market composition, two-wheelers account for 80.8% while passenger cars account for 12.9% market share. 4.77 million vehicles were exported by India in FY 2020, of which 73.9% were two-wheelers while 14.2% were passenger cars and 10.5% were three-wheelers (Invest India, 2021).

The leading manufacturers include Tata Motors, Maruti Suzuki India Limited, Mahindra and Mahindra, and Hero Motor Corporation (SIAM, 2021). The market share of Maruti Suzuki India is more than 50% of the Indian market. Tata Motors is a leading Indian firm, providing mobility solutions to over 175 countries (Raveendran, 2022). Hero Honda Motors Limited is the world's largest manufacturer of two-wheelers (IBEF, 2018). Production is organised in clusters (Ray and Miglani, 2018) with prominent clusters in Delhi NCR (with Maruti Udyog Limited and Hero Honda Motors Limited), Pune (with factories of Tata Motors, Bajaj Auto Limited) and Chennai (e.g. Hyundai factory).

Policy has played a key role in fostering growth in the Indian automobile industry (Ray and Miglani, 2016). Industrial policy has promoted local lead firms from the beginning, hence developing domestic capabilities in design, product development and engineering. When local firms lacked the expertise required by lead firms, the latter acquired western companies or formed international joint ventures. For example, in 2007, Tata Motors acquired the British luxury vehicle brands Jaguar and Land Rover from Ford (Sturgeon & Biesebroeck, 2011). The acquisition provided Tata Motors with the skills and technological knowledge essential to satisfy western consumers as well as to meet the safety and emission standards of mature markets.

Innovation in the Indian Automotive Industry

To discuss the innovations in the Indian automotive industry, we need to discuss GVCs and the role of lead firms in encouraging innovation, the need for Industry 4.0 adoption and the electric vehicle (EV) market.

Global value chains and lead firms

Vertical supply chain linkages with global lead firms provide suppliers access to foreign knowledge which may help them build up their technological capability. The governance of the GVCs and the role of the lead firm in encouraging and disseminating knowledge depends on the control the lead firm exerts over the chain. The nature of innovation in GVCs and the role of lead firms therein has been examined by Buciuni and Pisano (2021) who show that lead firms can adopt four distinct innovation models depending on i) the geographic dispersion of innovation and production and ii) the degree of control the lead firm exerts over production.

Global knowledge sourcing is a function of the horizontal linkages between lead firms and foreign organizations such as R&D centres that specialise in similar innovation-intensive value chain activities. The typical innovation process is dispersed across locations (within and outside the firm), actors (suppliers, consumers and users), who are interconnected through a network allowing the exchange of knowledge. The process of innovation could be decentralised and could occur at any value chain stage. The role of linkages, both internal and external, is important and the innovation performance of specific nodes across the value chain depends on what happens to the network as a whole.

The automobile value chain is spread across the globe. It is a mature industry with stable technology and high barriers to entry and exit. Globally, the top ten countries produce almost 52% (in terms of million units in 2019). The automotive industry is neither fully global nor fully local (Sturgeon et al. 2008). The degree of integration differs at various stages of the value chain.

India has relied more on home-grown lead firms to propel its industry, compared to other developing countries (Ray and Miglani, 2016a). A disadvantage of this approach is that the absorption of global best practices has been proceeding more slowly (Sutton, 2004). Nevertheless, the development of the Indian automotive industry has accelerated very quickly in the past several years. This improvement in the breadth and depth of local capabilities has been aided, most notably, by foreign acquisitions. Competencies in vehicle design and engineering have driven local lead firms from China and India to acquire distressed auto companies in western countries in the aftermath of the global financial crisis (Van Biesebroeck and Gereffi, 2008).

BOX 1: Tata Nano and the Case of Frugal Innovations

The Tata Nano case presents an alternative approach that combines technological innovation with frugality.

Objective:
The innovations in the Tata Nano car were manifold to keep the cost of the car to below USD 2000.

Challenge:
Create a design for a car which could deliver an innovative design that could be a proper 'four door' family car and not just a motorised 4 wheel motorcycle and most importantly, setting the target selling price of Rs. 1 lakh so as to compete with domestic rival Maruti 800, which was the cheapest car on the market at the time.

Approach:
- The Nano was the result of 5 years of R&D effort by the Tata Nano development team which commenced in 2003.
- The innovations were made in several parts of the car including the engine, steering, wheels, tyres, windshield washing system, gear shifter, etc.
- The engine used in the car was a four-stroke parallel 624 cc and was the result of a collaboration between Tata and Bosch. The engine was mounted under the rear seats.
- The rear-wheel-drive system in the car was developed by GKN Driveline India (a subsidiary of GKN), after experimenting with 32 variants of the driveshaft.
- Madras Rubber Factory-built tougher rubber tyres for the car. Denso came up with a unique windshield wiper that was used instead of the customary two.

Outcomes:
- The Nano's management decided to implement "concurrent engineering in real-time" by directly involving component suppliers in the early stages of product development rather than just providing them with technical specifications.
- Suppliers were encouraged to look at the current work and give their own practical ideas which could further inspire the frugal perspective. From the design phase itself, engineers were asked to be as frugal as they could to keep in mind the low-price promise while Tata Motors and its suppliers made consistent efforts to retain costs while maintaining the quality of each and every component.
- Components sourced were allowed to be developed as proprietary technology of the respective supplier so as to gain additional sources of revenue.

Source: Gaur and Sahdev, 2015.

As noted by Sturgeon and Biesebroeck (2010), every aspect of vehicle development and production, including design and engineering, existed in local firms from the beginning, which allowed the industry in India to surge forward. While Indian firms had traditional strengths in casting, forging and precision machining, and fabricating (welding, grinding, and polishing) (Ray and Miglani, 2016b), they have acquired engineering capabilities to adapt the design to local requirements (Miglani, 2019) through frugal innovation.

Frugal innovation has been defined as a process whereby the complexities of innovation are reduced to decrease the cost of goods and provide products with lower prices in a high-volume market (Gaur and Sahdev, 2015). Such innovation has played a key role in the development of the Indian automotive sector. Frugal innovation has the following elements: (1) a customer-specific value proposition, (2) minimal use of resources, and (3) affordable cost of ownership. In particular, engine, drive transmission, and steering parts are among India's competencies.

Industry 4.0 adoption

Industry 4.0 is a driver for global competitiveness in the Indian automotive sector. Digital technologies have now matured to a point where they can transform operations. However, digitisation is not just in manufacturing, but also for add-on processes like sales, configuration, financing, insurance and registration – optimising end-to-end processes. This is exemplified by Mahindra & Mahindra which successfully modernised their technology landscape and enhanced their overall operations through Industry 4.0 adoption. This was achieved with the migration of SAP to a secure managed cloud environment whilst moving to a micro-services-enabled open stack architecture.

The manufacturing landscape is changing, and countries are constantly being challenged on technical capabilities and manufacturing value additions. Therefore, Industry 4.0 adoption is a must for India. India faces specific competition from China and Europe and there is a risk of being crowded out by the increasing technical capabilities of these regions that also focus on the medium value segment that India has always prominently operated in.

The ability to embrace Industry 4.0 and use the opportunities that will rapidly (and, in many instances, unexpectedly) present themselves will be a key to success in the new global market. For example, Volvo Group and Eicher Motors Limited has set up an Integrated Data Management (IDM) platform which delivers end-to-end digital continuity along with digital twins for virtual validation (digital mockup), virtual manufacturing validation, as well as planning. It is clear that Industry 4.0 presents tremendous opportunities, and this fact highlights the need for a highly trained and flexible workforce and a production capacity that can answer the needs of tomorrow as well as those of today.

Reports peg the smart factory industry to touch USD 215 billion by 2025 and all major economies are likely to accept it. With the emergence of digital technologies, there is a need for a systematic approach to understanding the opportunities available for the automotive industry. With digital channels gaining popularity among India's consumers, which was boosted during the COVID-19 pandemic, automotive manufacturers must develop more direct options (business to customer). An example of this is Hero MotoCorp's partnership with ADLOID for the launch their AR showroom. The augmented reality showroom takes digitisation a step ahead by allowing customers to explore, configure and experience the Hero MotoCorp products in their homes. In addition, TATA Motors partnered with ADLOID for the AR launch of its new Safari 2021 model.

Achieving greater resilience in operations, especially the product, manufacturing, and supply-chain dimensions is crucial. Amid uncertainties as experienced during the COVID-19 pandemic, it is evident that companies will need operational resilience across the entire value chain. With a fairly advanced ecosystem of design, development and manufacturing, the automobile industry should continuously work towards environmental sustainability.

Electric vehicles (EVs)

The emergence of EVs has been necessitated due to the exigency of climate change and the need for reduction or phasing out of fossil fuel use. In general, EVs are seen to reduce emissions and noise pollution, as well as lower fuel and maintenance costs. In the Indian context, the Government of India (GoI) further provides tax and financial benefits for the user. In addition, there are also few policies or schemes that focus on environmental sustainability implemented by the GoI, such as: the National Mission for Electric Mobility Plan (NMEMP), Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME I and FAME II) and the Production Linked Incentive (PLI) schemes for Advanced Cell Chemistry

BOX 2: Mahindra & Mahindra's Connected Factory

Mahindra & Mahindra's Chakan plant opened in 2010 and was one of India's largest greenfield projects, with an objective to create a 'factory of the future'.

Objective:

Build a 'connected factory' with agility and flexibility, connecting the shop floor to the top floor for IT-OT integration (Information Technology-Operational Technology), with the Internet of Things and associated technologies.

Challenge:

Such a futuristic factory had to be adaptable to rapid changes in customer demand, emerging technologies, equipment used and business processes.

Approach:

- A high-level design document was created for the IT-OT integration, based on the business processes and requirements.
- An inventory of the information to be shared in real-time between the shop floors and the enterprise resource planning ERP application was decided.
- The engineering framework implemented by the team enabled the acquisition of data from all the connected, networked sources of data.
- The Track & Trace initiative connects all of the 20,000 tools on the shop floor to determine their location.
- Digital manufacturing enabled the virtual simulation of specific scenarios so that the team could carry out a 'what-if' type of analysis and be proactively prepared.

Outcome:

- Mahindra was able to achieve centralised reporting of key metrics and early fault detection leading to a lower defect rate and better quality and change over time reduction with the 'connected factory' implementation.

(ACC) batteries and auto and auto components. These are addressed in detail in the 'Policy Review' and 'Results' sections of this report.

India's EV market is expected to grow by 90% to reach USD 150 billion by 2030. In 2021, 329,190 electric vehicles were sold in India, of which 90% were electric 2-wheelers or 3-wheelers. The share of 4-wheeler EVs was 4% (EV Reporter, 2021). In 2021, nearly 50 companies proposed investments worth over INR 98,800 crore in the Indian automotive sector. About half of the total investments were on electric mobility, suggesting that both the legacy players and the newcomers chose to develop these technologies in-house, rather than pursuing inorganic growth (Mishra, 2022).

Globally, only close to 2% of new vehicles sold are electric. Some Indian subsidiaries of leading multinational automotive manufacturers, such as Ford and Volkswagen, are increasing the scale of their Indian operations as well as ramping up their exports. Indian manufacturers can also become hubs for innovation, both domestically and in markets abroad, supplying complete products, aggregates, or components worldwide.

Innovation in the context of EVs involves moving from lithium-ion batteries to batteries that charge even faster. There are problems in battery manufacturing from the Indian point of view –the raw materials are not found in the country and the chips and semiconductors are not produced locally either. In the Indian context, job losses are a major concern when it comes to manufacturing autonomous vehicles, while in other parts of the world, the trend is towards buying them.

A myriad of challenges exists with regard to EV adoption in India. Key challenges and barriers in the adoption of EVs include the following:

1. Insufficient charging infrastructure
2. High cost of EVs and dependence on imported batteries
3. Inadequate technological know-how
4. Stringent conditions for availing subsidies - various riders placed around eligibility conditions have largely defeated the purpose
5. Consumer hesitancy due to lack of public awareness
6. No regulatory framework for charging service providers to participate in the power market for demand response
7. A cumulative investment of ~Rs. 12.5 trillion (USD 180 billion) in vehicle production and charging infrastructure would be required until 2030 to meet India's electric vehicle (EV) ambitions

A viable ecosystem and necessary infrastructure are needed to support EVs. A move into EVs will also help suppliers diversify their portfolios and reduce risks related to market demand. Industry disruptions also create a huge opportunity for automotive suppliers to double down on building a strong position in the global EV supply chain. Government policies should orient towards addressing the challenges faced by the Indian EV market to become a global manufacturer.

Way forward

The Indian automotive sector is undergoing a massive transformation, and much will be driven by Industry 4.0 and the extended digitalisation across the value chain. Automotive manufacturers should therefore focus on the following priorities to harness the power of digital technologies and the new dynamics related to a strengthened sectorial system of innovation.

Operations efficiency

While the sector must move forward in new directions to stay competitive, production efficiency is still a key driver for competitiveness and must remain a priority. Automotive manufacturers need to continually look for ways to improve their operations, leveraging new technologies and integration opportunities (vertical, horizontal and end-to-end digital integration) that will provide manufacturers with the agility, automation, and efficiency they need to meet new demands.
The introduction of disruptive technologies such as electric vehicles, connected cars, and autonomous driving, calls for further attention to optimise the production processes and operations when manufacturers look forward to repurposing the same facility. As OEMs and suppliers ramp up EV production, there will be numerous changes in the manufacturing processes with more robotics and automation used to assemble smaller parts and subassemblies with minimal tolerances.

Maintenance efficiency

The operations have a strong dependency on the condition and efficiency of the production tools and assets. While today's smart assets (cyber-physical systems) are more efficient, productive and safer than their predecessors, they also require a greater frequency of scheduled upkeep and maintenance. They process a lot of data giving an early indication of performance issues. Advanced capabilities like condition monitoring, predictive maintenance, analytical troubleshooting, root cause analysis (RCA), decision-making and other critical processes, can therefore be leveraged to move away from reactive maintenance to scheduled maintenance and scheduled maintenance to predictive maintenance, to optimally manage asset condition, thus reducing the total cost of ownership.

Energy efficiency

Asset-intensive operations are also fairly energy intensive. Focusing on energy-intensive operations both in legacy and modern plants, opens up significant opportunities to reduce energy demand and implement energy-efficient operations to gain substantial benefits and improve overall environmental concerns. In addition, energy efficiency is crucial to reducing the pollutant emissions into the atmosphere and the automotive manufacturers find it challenging to increase the output of their products and yet adhere to energy efficiency practices and technology investment. Therefore, taking total control of energy efficiency in automotive manufacturing continuously leads to new opportunities for energy reduction and a significant contribution to sustainable energy use.

Information efficiency

As the automotive industry is faced with a dynamic set of challenges, one area to stand out and differentiate itself is by moving away from paper-based processes to data-driven insights. Data across the value chain can analyse data for anomalies, generate actionable insights

BOX 3: Digital Transformation at Bharat Forge

Objective:

Pune-headquartered global metal forging leader, Bharat Forge intends to have zero unplanned downtime in the hydraulics, pneumatics, and electronics sectors.

Approach:

The company has kickstarted a digital transformation journey to improve operational efficiency at its manufacturing plants over the next five years.

Outcomes:

- Bharat Forge has achieved Overall Equipment Effectiveness (OEE) by over 15% in several of their forging lines, using Nasdaq-listed IoT firm, PTC Inc's digital manufacturing solutions.
- As part of its "Industry 4.0 Center of Excellence" project in partnership with PTC Inc., Bharat Forge has pursued an end-to-end digital transformation for two of its manufacturing plants, including the reskilling of over 2,500 engineers.

and provide powerful capabilities for generating an enormous boost to achieve better data-driven decisions in production operations and across the value chain. In addition, the vehicle of the future will feature lots of high-end technology such as autonomous, connected, electrified, and shared (ACES) in-vehicle systems. This calls for common platforms that will enable an ecosystem of connected vehicles and emerging services, such as location-based marketing, intelligent driving, and map creation or enhancement, aggregating the data generated by vehicles and roadside technologies.

Workplace efficiency

The growth in 'electric drives' and the digitalisation of vehicles calls for new technologies and skills. The automotive industry should therefore invest in human capital in training the workforce to adapt to new technologies and state-of-the-art manufacturing operations. An attractive workplace plays a pivotal role in attracting and retaining talent. In addition, a more automated 'smart workplace' can also enhance efficiencies, support innovation, and increase employee satisfaction.

Ecosystem efficiency

OEMs have traditionally worked hand in hand with tier-one suppliers, but today the emergence of a broader ecosystem can be seen, opening up opportunities for new business models and providers. With ACES trends fundamentally transforming over the coming years, existing business models will be challenged. This will impact established supply chains as they become more complex and supply relationships become extremely interwoven at a global level. Automotive OEMs should strengthen their position within the sectorial system of innovation focusing on critical technologies of autonomy, connectivity, electrification, and shared mobility. While the new technologies will undoubtedly generate enormous value, it is hard to predict the timing and flow of economic profit.

End user efficiency

Automotive OEMs currently have control over the end customer (to a certain degree) and also the most important control point in the industry—the vehicle itself. However, to stay relevant in an ACES world, manufacturers must re-evaluate their overall approach to user experience, understand where the control points will be in the future, and decide how much of the 'pie' they are willing to share to form a thriving innovation network. Most vehicles already allow customers and OEMs to monitor, and to some extent, interact with them. As we move toward an increasingly autonomous future, new customer interfaces and services, as well as radical improvements in the adoption of new features for safety, convenience, experience, and environmental impact will, taken together, disrupt existing business models on an almost inconceivable scale.

5.

Policy Review

Policy Review

The 4IR, also known as Industry 4.0, brings with it a host of scientific and technological breakthroughs that not only disrupt businesses but also challenge the existing national policies and regulatory frameworks. The 4IR confers unique advantages for the automotive industry, that has always been at the forefront of global technological innovation (PwC, 2017). This chapter reviews national policies to see if the policy landscape is conducive to effectively support India's automotive sector. It is an attempt to identify divergences between sectoral priorities and policies, as well as an attempt to review the competencies of and coordination between various government bodies engaged in policymaking. Furthermore, the chapter examines the directives established by Indian policymakers to discern the sector's competitiveness, being mindful of how synergies among the five key actors in the automotive sectorial system of innovation (government, industry, KBIs, intermediaries and arbitrageurs) can influence policy implementation.

The Indian automotive industry in many ways has been shaped by the government's industrial policy and nurtured in the microeconomic environment it helped to create (Miglani, 2019). It has evolved through policy regimes characterised by an era of protectionism (1950-1983), deregulation (1983-1993) and liberalisation (post-1993). In addition to direct impact through fiscal policy instruments, the industrial policy also contributed to the development of innovation and technological capabilities at the firm level (Kale, 2012). Liberal policies of the 1990s exposed automotive firms to new competitors and encouraged them to innovate and acquire advanced technology through partnerships and investments in research and development (R&D). At the same time, the industrial policy protected domestic firms by imposing local content requirements that led to the development of basic capabilities in automotive manufacturing and laid the foundations of the auto component industry (Kale, 2012).

As part of India's transition from a closed to an open economy, the government opened up the automotive sector to Foreign Direct Investment (FDI) in the 1990s and also progressively relaxed import barriers (McKinsey, 2006). The FDI policy for the automotive sector allowed 100% FDI under automatic route with no minimum investment criteria (FDI India, 2021). In keeping with the view that FDI generates positive spillovers for local firms, India's policy approach has been to attract FDI to serve the local market and to impose local content requirements to stimulate assembly and the local supply base (Ray and Miglani, 2018). This determined thrust towards indigenisation is considered a key policy measure responsible for enhancing technological capabilities in the automotive sector (Sagar and Chandra, 2004).

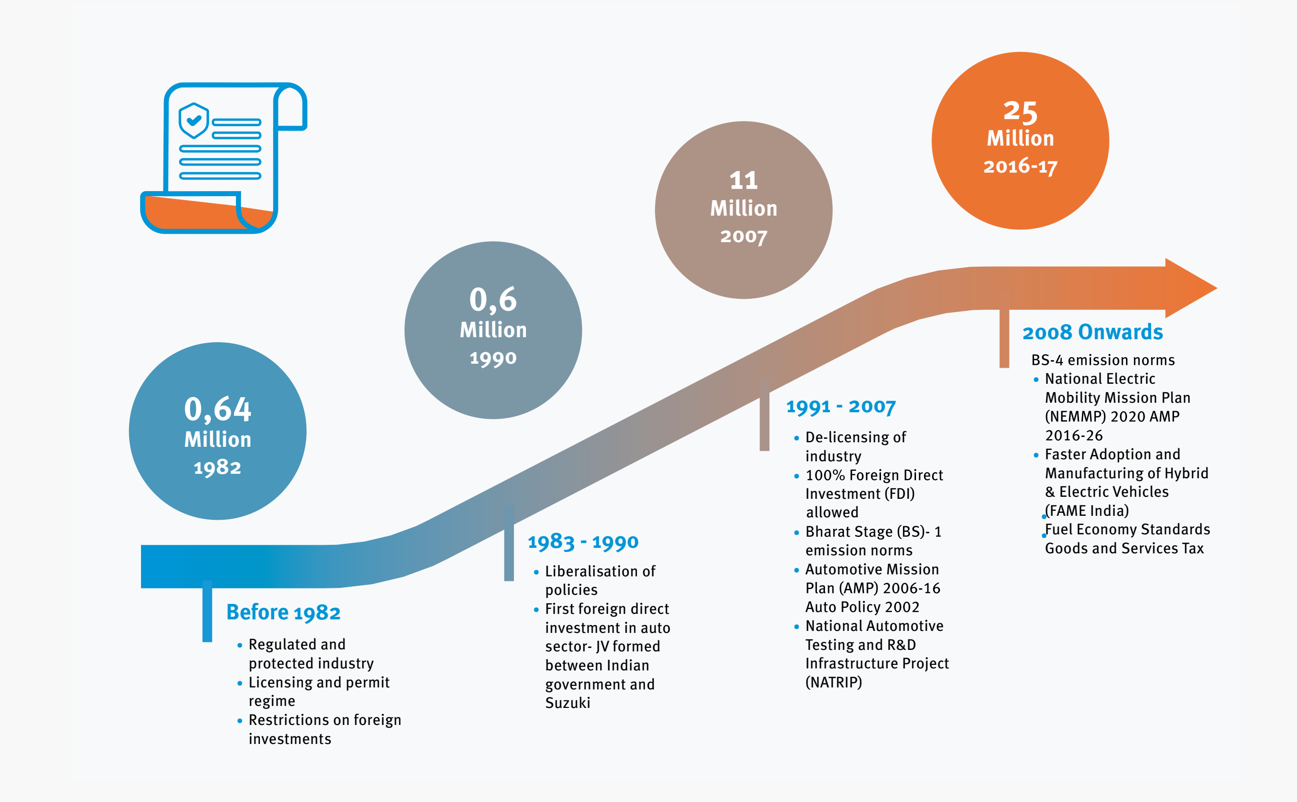
A lot has happened in the automotive sector post-liberalisation as it emerged as a 'sunrise sector' in the Indian economy. The past decade has been a witness to policies and initiatives launched to support Industry 4.0 and green mobility. The Government of India and the Indian automotive industry articulated their collective vision for the future of the Indian automotive sector through the Automotive Mission Plans spread over two decades that seek to define the path of the evolution of the automotive industry in India. Moreover, many analogous policies were launched in parallel that supported the growth of the automotive sector in multiple ways.

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

Core Policies of the Indian Automotive Sector

With the intention of increasing the manufacturing output and employment in the sector, the "Automotive Mission Plan 2006-16" (AMP 2016, hereafter) was the foremost sector-specific plan released on a pan-India scale. "AMP 2016 was the outcome of a protracted in-depth dialogue with all stakeholders (industry, academia, authorities) over a period of fifteen months" (Department of Heavy Industry (MHI), 2006; p. ix).

Figure 2: Timeline of Major Policies and Regulations for the Automotive



The key objectives of AMP 2016 were as follows:

a. To establish India as a key player in the manufacture and export of two, three wheelers, tractors and more importantly, auto components.
b. To provide favorable investment opportunities and appropriate tariff policy for the automobile sector.
c. To integrate automation and IT in manufacturing and to promote infrastructure development in the auto clusters.
d. To facilitate expansion of domestic demand and to encourage exports.
e. To support development of R&D and incentivise modernisation of the sector.
f. To undertake labour reforms and ensure availability of trained manpower.
g. To create world class infrastructure for testing, certification and homologation under the "National Automotive Testing and R&D Infrastructure Project" (NATRiP).

The government states that AMP 2016 had many of its objectives/targets completed (MHI, 2016). It achieved its target of generating an incremental 25 million jobs as well as the sales target (number of units sold) of commercial and passenger vehicles. India's emergence as a global hub for small cars is one of the key accomplishments of AMP 2016 (MHI, 2016). Apart from that, the sector achieved a significant quantum of investments from global and local Original Equipment Manufacturers (OEMs) as well as component manufacturers, exceeding the target of ₹ 1.5 trillion (MHI, 2016).

Despite these accomplishments, AMP 2016 faced two main challenges that were taken into consideration while drafting its successor, the AMP 2016-26 (AMP 2026 hereafter). The first challenge pertained to the low involvement of government bodies and institutions at all levels (central, state and local) in the implementation of AMP 2016 and the lack of coordination among them. Secondly, AMP 2016 was positioned as a document primarily meant for the manufacturers and not positioned keeping in mind other interest groups or stakeholders, which is why AMP 2026 seeks to be more inclusive by design than its predecessor (MHI, 2016).

The AMP 2026 Vision Statement announces that the Indian automotive industry will be among the global top three in the fields of engineering, manufacturing and exports by 2026, encompassing the promotion of safe, eco-friendly and affordable mobility for the majority

(MHI, 2016). The 'Final Draft' document released by the Government of India in January 2016 for the next phase of the automotive mission plan lists the core objectives of AMP 2026 below:

a. To propel the Indian automotive industry to be the engine of the "Make in India" programme.
b. To make the Indian automotive industry a significant contributor to the "Skill India" programme and make it one of the biggest drivers of employment creation in the country.
c. To enhance mobility, keeping in mind the environmental protection and affordability aspects.
d. To become one of the major automotive export hubs of the world.
e. To promote comprehensive and stable policy dispensation for all regulations and policies that govern the auto sector.

"AMP 2026 seeks to define the trajectory of the evolution of the automotive ecosystem in India including the glide path of specific regulations and policies that govern research, design, manufacturing, technology, import/export sale, use, repair and recycling of automotive vehicles, components and its ancillary services"(MHI, 2016; p. vii). It emphasises that all regulations and policies impacting the sector should be comprehensive in scope and scale and should be implemented harmoniously across the nation. AMP 2026 mandates to "position itself as the guiding document for all institutions that frame policies impacting the manufacture and use of automotive products in India" (MHI, 2016; p. xi). Thus, it recommends interventions in policy areas (with relevance to the automotive sector) such as investments and trade, tariffs, trade agreements, fiscal and taxation measures, exports, environment protection and global competitiveness. It purports to make inputs to supporting policies of the Government of India that have a huge impact on the growth and well-being of the automotive industry (MHI, 2016).

With regards to the trade policy of the government, AMP 2026 supports the rationalisation of custom duties on raw materials used in automotive components and vehicles; and calls for an emphasis on the domestic capacity creation of imported items, such as automotive electronics, in order to boost local manufacturing and to support the "Make in India" initiative. Though it welcomes the thrust given to promote exports in the "Foreign Trade Policy 2015-20" by way of consolidation of various export promotion schemes and further simplification of procedures, it also calls for an additional duty drawback to be given to both vehicle and auto component exports in order to improve the export potential of the automotive sector.

Considering the competitive nature of the sector, AMP 2026 suggests that Free Trade Agreements should only be signed with countries that do not have a significant automotive production base. Such inputs are expected to ensure that the automotive industry in India is subjected to a fair and predictable governing environment (MHI, 2016).

The Indian automotive sector needs adequate fiscal support and as AMP suggests, it can be in the form of lower level of taxes, weighted tax deduction for R&D expenditure and accelerated depreciation rates for the capital equipment manufactured in India. It further supports setting up of a "Technology Acquisition Fund" that finances acquisition of cutting-edge technology by the automotive sector.

In the area of environment protection and safety, AMP 2026 pronounces a glide path for fuel usage by automobiles in India and supports the establishment of emission norms based on internationally accepted methodologies. It also advocates the formulation of appropriate regulations along with monitoring and enforcement agencies to check proliferation of spurious components. It supports the implementation of an appropriate inspection and certification policy along with establishing necessary infrastructure across the nation.

Lastly, "AMP 2026 envisages that the government and the Indian automotive industry will work together to address all the key issues to take India to its rightful position in the global automotive industry's sweepstakes" (MHI, 2016; p. 64).

Complementary to AMP 2026, the "National Automotive Policy" (NAP 2018) has been drafted by MHI (on the lines of NAP 2002) for the holistic development of the automobile sector in India through a comprehensive policy framework. With the objectives mainly aligned with AMP 2026, it identified five key areas for policy intervention, namely: a) innovation and R&D, b) vehicle manufacturing, c) components manufacturing, d) green mobility and lastly, e) an enabling ecosystem for achievement of policy objectives.

Though it envisions growth of the industry as per the goals of AMP 2026, it prescribes policy guidelines specific to automotive value chain focus areas to address the issues faced by different stakeholders. Another unique aspect of the draft NAP 2018 is that it seeks to establish an automotive ombudsman to strengthen the grievance redressal system with an emphasis on quality and compliance standards. Effective implementation of any policy requires coordination among government bodies. NAP 2018 proposes the formation of a nodal body for the industry to act as a consultative agency for all ministries engaged in the formulation of automotive-related policies and regulations. The body will be responsible for reviews every four years and recommend course corrections. "It will also serve as the repository of technical domain expertise and data on all aspects of automobiles and their manufacturing and be the technical advisor and the secretariat. The proposed nodal body will be a two-tiered structure with an apex body supported by the National Automotive Council (NAC)." (MHI, 2018; p. 29).

Policies for Environment Protection and Safety

The growth of the automotive industry poses key challenges of rising energy costs, increasing oil import bills, and faster depletion of traditional energy sources, among others. Launch of the "National Electric Mobility Mission Plan 2020" (NEMMP) was part of the government's plan to mitigate these challenges and reduce the impact of mobility on the environment (MHI, 2013). In accordance with the objectives of AMP (2016), NEMMP promotes the sales and manufacturing of electric vehicles through various reforms. In order to boost its "Make in India" initiative, the government planned to make the electric vehicles market in India self-sustaining. Accordingly, the MHI formulated a scheme namely FAME (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India) aimed at making xEV (hybrid and electric vehicles) self-sustaining by increasing domestic capabilities for product and technology development. It proposed a slew of measures to achieve the objectives of NEMMP.

Further, in order to strengthen and institutionalise the collaboration between the Ministry of Heavy Industry (MHI) and Department of Science & Technology (DST) in R&D and Technology Development in Electric Mobility, a joint programme called the "Technology Platform for Electric Mobility" (TPEM) was set up in 2016. Its aim is to provide a collaborative platform for developers, suppliers and automotive manufacturers to work together to develop technologies and products that cater to the development of e-mobility (Mukherjee, 2017). Besides this, responsibilities of the platform also include updating the technology roadmap of NEMMP and FAME, maintaining an updated and prioritised list of relevant R&D programmes and developing white papers on critical technologies (MHI, 2016). MHI being a nodal agency has many platforms and policies formed under its purview with one of them being the Development Council for Automobiles and Allied Industries (DCAAI). The DCAAI was constituted in 2008 for the productive utilisation of the Cess fund allocated to MHI's annual budget to promote R&D projects for automobiles and allied industries. The council is chaired by the Secretary (MHI) and it meets at least twice a year to discuss issues related to the development of the auto sector. It consists of 25 members and has projects approved amounting to ₹135 million and ₹88 million for the years 2018-19 and 2019-20, respectively[3].

Phase I of the FAME scheme, under the ambit of NEMMP, was launched on 1st April 2015. It promoted manufacturing and encouraged the buying of reliable, efficient and more importantly, affordable electric/hybrid vehicles to ensure sustainable growth. Initially, launched for a period of 2 years, it was subsequently extended to 31st March 2019. Phase I had four focus areas, namely: (i) demand creation, (ii) technology platform, (iii) pilot project and (iv) charging infrastructure.

While Phase I was still ongoing, a "Draft Taxi Policy" for the promotion of sustainable public transport was introduced by the Ministry of Road Transport and Highways (MoRTH) in December 2016. It enumerates provisions for e-rickshaws with a view to promote urban mobility. The policy suggests that e-rickshaws can be proactively used for last mile connectivity in cities as these offer low cost and zero-pollution transportation. With nearly 32% of the Indian population living in urban areas (Census, 2011), there has been a continuous shift in the population. Seeking to get the most out of this opportunity, the Ministry of Housing and Urban Affairs launched the "Urban Green Mobility Scheme" in November 2017 for the promotion of a low carbon sustainable public transport system to reduce the carbon footprint.

Phase II of the scheme came into effect from 1st April 2019 with a larger allocation of ₹100 billion and an implementation period that is spread over 3 years. Apart

3 Sourced from: https://MHI.nic.in/UserView/index?mid=2477

from budget, the policy brings in changes in demand incentives and target number of vehicles, along with new xEVs technology definitions and performance and eligibility criteria for vehicles (MHI, 2019). It advocates proactive support from the state governments to complement the efforts of the central government for the promotion of e-mobility. The MHI is the nodal agency for laying guidelines. A committee comprising secretaries of various ministries named the Project Implementation and Sanctioning Committee (PISC) and headed by the Secretary (MHI) was constituted to oversee the monitoring, sanctioning and implementation of Phase II. As opposed to Phase I, Phase II focuses more on public transportation, projecting it as an environmentally friendly and affordable transport option for the masses. Furthermore, the "Phased Manufacturing Programme" (PMP) announced alongside Phase II, primarily focused on providing an impetus on the manufacturing of e-vehicles, sub-assemblies, parts and sub-parts through a graded duty structure in order to increase value addition and capacity building in the country. The PMP announced an increase in the tariffs for the import of battery modules, electric buses and trucks to promote indigenous production. Until August 2019, a total of 5,595 buses for 64 cities for -intra and inter-city operation were sanctioned under Phase II (MHI, 2019). In addition, for the development of charging stations, the scheme sanctioned 2,636 stations in 62 cities across 24 states/UTs. As per the latest data available on the FAME II website[4], over 50 models are available under Phase II and over 20,000 vehicles have been sold with more than ₹500 million being disbursed.

Production Linked Incentive (PLI) schemes for automobile and auto components (₹ 25,938 crore) and for Advanced Chemical Cell (ACC) batteries (₹ 18,100 crore) along with the FAME scheme (₹ 10,000 crore) are intended to enable India to leapfrog to environmentally cleaner, sustainable, advanced and more efficient EV-based systems (PIB, 2022).

Policies for the Future Workforce

As India is home to the largest youth population of the world, there is an imminent need to cater for the ever-growing technical aspirations and provide employment, driven by skill development and R&D. An Ernst & Young and National Association of Software and Service Companies (NASSCOM) study (2017) on the future of jobs in India found that by 2022, around 46% of the workforce will be engaged in entirely new jobs that do not exist today or will be deployed in jobs that require radically changed skill sets. In this ever-changing and increasingly complex world of today, it is all the more important to prepare a dynamic and evolving workforce that is fluent in Science, Technology, Engineering and Mathematics (STEM). The STEM workforce is critical for the economy and global competitiveness and the Indian government is working for STEM enhancement through smart class platforms, upgradation of library infrastructures, implementation of library management systems and gamification. India still needs a new approach to education and skill development. When the National Policy on Education 1986/1992 was formulated, it was difficult to predict the path of technological innovation, particularly the impact of disruptive technologies, which is why the government initiated the process of formulating a new education policy. The "National Education Policy 2020" clearly states that "our present education system's inability to cope with these rapid and disruptive changes places us (individually and nationally) at a perilous disadvantage in an increasingly competitive world. India must take the lead in preparing professionals in cutting-edge areas that are fast gaining prominence such as artificial intelligence, 3-D machining, big data analysis and machine learning, among others in technical education." The National Education Policy 2020 also endorses the recommendations made by NITI Aayog pertaining to the use of emerging technologies for improving access to and the quality of education as well as for preparing tomorrow's generation to leverage technology disruptions to the country's advantage.

AMP 2026 recognises that among all the sectors, the automotive sector offers one of the highest potentials for providing skills to youth and is more proactive about up-skilling. One of the objectives of AMP 2026 is to be a prime exporter in terms of technology and research, so policies and councils for the same allow expedite management and arrange for vital inputs for the sector. It envisages a bigger role for the Automotive Skill Development Council (ASDC) by making it an apex industry body for skill development under various programmes by the government and an independent

4 Sourced from: https://fame2.heavyindustry.gov.in/

testing and certification agency for sector skills. ASDC is the first sector skill council of India[5] set up as part of the initiatives taken to strengthen the automotive sector under the AMP 2016. Currently governed by the National Skill Development Corporation (NSDC), ASDC is working to understand the dynamic workforce requirements of the automotive industry and accordingly develop digital learning models. ASDC is adding new job roles (called "Qualification Packs" or "QPs") to address the policy initiative of moving over to electric mobility as outlined in the FAME II initiative. Emerging job roles with respect to the 4IR are being validated with the support from industry and academia. Existing QPs are getting enhanced by the ASDC Expert Group, consisting of members from industry. These QPs are based on robotics process automation, 3D printing and big data analysis (ASDC Brochure, 2019).

Where India tops in producing science and engineering graduates, it severely lags behind in the number of researchers who drive innovation. According to the "Science and Engineering Indicators 2018" report released by US-based National Science Foundation, the US tops spending on R&D, followed by China. However, India does not rank among the top 10. The Science and Technology Innovation Policy (STIP) 2013, released by the Department of Science and Technology (DST), thus aims to accelerate the pace of discovery and increase the quantum of science-led innovations for a faster and sustainable and inclusive growth. It lays focus on areas "such as prioritising critical R&D areas, promoting interdisciplinary research, creating an environment for private sector participation in R&D, and supporting STI-driven entrepreneurship viable models" (STIP, 2013; p. 14). In 2008, a Science and Engineering Research Board (SERB) was established under DST for funding research in frontier areas of science and engineering. Industry Relevant R&D (IRRD) is one of the schemes launched by SERB in 2016 that aims to utilise the expertise available in academic institutions and national laboratories to solve industry-specific problems. It is constantly looking for proposals whose outcomes will bring new scientific and technological innovations (SERB, 2016).

The draft STIP 2020 outlines the need for short-, medium-, and long-term mission mode projects for building a research and innovation ecosystem aimed at evidence and stakeholder-driven STI planning, information, evaluation, and policy research in India. Establishment of a National STI Observatory as a central repository for all data related to the STI ecosystem is an objective of the policy. This observatory will consist of an open centralised database platform for all financial schemes, programmes, grants and incentives in the STI ecosystem. It will be centrally coordinated and organised in a distributed, networked and interoperable manner among relevant stakeholders (DST, 2020).

Another component of STIP 2020 is a forward-looking Open Science Framework (OSF) that will be built to provide access to scientific data, information, knowledge, and resources to those engaging with the Indian STI ecosystem on an equal partnership basis. While all data used in and generated from publicly-funded research will be available to everyone under findable, accessible, interoperable and reusable (FAIR) terms, a dedicated portal will also provide access to the outputs of such publicly-funded research through the Indian Science and Technology Archive of Research (INDSTA) (DST, 2020).

Through skills building, training and infrastructure development, the government aims to improve STI education making it inclusive at all levels and more connected with the economy and society. Interdisciplinary research will be promoted through Higher Education Research Centres (HERC) and Collaborative Research Centres (CRC) that can also provide research inputs to policymakers and bring together stakeholders. Using ICT, online learning platforms will be developed to address the issue of accessibility and to promote research and innovation at all levels. Faculty members will be upskilled through Teaching-Learning Centres (TLCs) to improve the quality of education (DST, 2020).

If India intends to leverage 4IR concepts and technologies, it has to expand the skill base of its workforce and create a robust ecosystem for research and innovation. Since the automotive industry is at the forefront of adopting 4IR technologies, it will be the first to witness an increased demand for new skills in the domain of ICT, Human-Machine Interaction (HMI), Cyber-Physical Systems (CPS), data analytics, etc. A Future workforce equipped with technology-driven education and 4IR-related skills can also ensure India's competitiveness in the dynamic global labour market.

5 Sourced from: https://www.asdc.org.in/skilldevelopment

Policies Embracing 4IR

A closer look at the policies adopted by India since the 1990s reveals a clear intention to shift from an agriculture-based economy to one that emphasises manufacturing to drive economic growth and jobs. Recent initiatives like "Make in India" and "Skill India" show the government's resolve to encourage manufacturing in the country; and the automotive sector has long been identified as having the competitive advantage and potential to fuel the rapid growth of manufacturing. But with the introduction of the 4IR, the GoI is formulating a "National Policy for Advanced Manufacturing" as part of India's plan to embrace the 4IR and exploit the huge potential of emerging technologies such as additive manufacturing, cloud computing, Artificial Intelligence (AI), the Internet of Things (IoT) and robotics.

Another initiative in this direction is the Smart Advanced Manufacturing and Rapid Transformation Hub (SAMARTH) - Udyog Bharat 4.0. It is an initiative by MHI to set up 4IR centres (demo-cum-experience centres) across the country for promoting smart and advanced manufacturing to help SMEs implement the 4IR (automation and data exchange in manufacturing technology). This is being done to enhance competitiveness in the Indian capital goods sector and to build awareness about the 4IR among Indian manufacturing industries. There is no escape from integrating principles of the 4IR with the "Make in India" initiative if indigenous manufacturing has to win against global competition. Such initiatives have been taken to ensure that the automotive sector remains relevant in terms of making its products and manufacturing processes innovative across the automotive ecosystem.

Disruptive technologies, such as AI hold great potential for the manufacturing sector, particularly the automotive sector. Recognising this, the Finance Minister of India, in his budget speech for 2018 – 2019, mandated the premier policy think tank of the government - NITI Aayog - to establish the National Programme on AI with a view to guiding the research and development in new and emerging technologies. A discussion paper entitled "National Strategy for Artificial Intelligence: #AIForAll" was released by NITI Aayog in June 2018 in which it emphasised that AI-enabled mobility solutions can effectively address the challenges faced by the Indian automotive sector.[6]

The emerging technologies also need to be integrated in the supply chain of the automotive sector so that the benefits can be reaped by all participants of the supply chain. Logistics being an important area of the supply chain have a crucial role to play in the complex ecosystem of supply chain partners. The draft "National Logistics Policy" (NLP) released by the Department of Commerce in 2019 allows for the seamless movement of goods through a single window with a focus on employment, skills and making small and medium enterprises competitive. It aims to "enhance efficiency across the value chain through increased digitization and technology adoption" (Department of Commerce, 2019; p. 3). This can greatly ease the process of adoption of digital supply chain solutions to meet the increasing product complexities and changing market dynamics of the automotive sector (CII and EY, 2019).

To keep pace with global technology and promote cutting-edge research, a project named the "National Automotive Testing and R&D Infrastructure Project" (NATRiP) was set up in July 2005 (under AMP 2006-16) as an independent society for creating core global competencies by having state-of-the-art automotive testing, homologation and R&D infrastructure facilities in India. Set up with an initial outlay of ₹17.18 billion that was increased to ₹22.88 billion and finally hiked to ₹37.27 billion in 2016, it is one of the largest and most significant initiative in the sector so far (NATRiP Annual Report, 2017-18). There are a total of seven centres under its ambit; four of them are green field projects (see Table 1) and set for different areas of automotive testing with state-of-the-art infrastructure while three facilities have been upgraded with new technology and equipment.

6 Building further on the National Strategy on AI, Sourced from: https://www.niti.gov.in/sites/default/files/2021-02/Responsible-AI-22022021.pdf, the first part of the following approach paper titled "Towards Responsible AI for All", aims to establish broad ethics principles for design, development and deployment of AI in India – drawing on similar global initiatives but grounded in the Indian legal and regulatory context. The second part of the strategy, which will be released shortly, explores means of operationalisation of principles across the public sector, private sector and academia. Within this framework, it is hoped that AI can flourish, benefiting humanity while mitigating the risks and is inclusive bringing the benefits of AI to all.

TABLE 2: Centres of Excellence under NATRiP

Facility	Location	Centre of Excellence (COE)
International Centre for Automotive Technology (ICAT)	Manesar	Components, noise, vibration and harshness (NVP)
Global Automotive Research Centre (GARC)	Chennai	Passive safety and infotronics
National Institute of Automotive Inspection, Maintenance & Training (NIAIMT)	Silchar (Assam)	Automotive inspection and training (hilly terrain)
National Automotive Test Tracks (NATRAX)	Pithampur (Indore)	Vehicle dynamics and R&D tracks

Source: http://www.natrip.in/download/Natrip_architecture.pdf

The two existing facilities, the Automotive Research Association of India (ARAI-Pune) and the Vehicle Research & Development Establishment (VRDE – Ahmednagar) have been upgraded with new technologies. The International Centre for Automotive Technology (ICAT) is currently undergoing upgrading for passive safety and test tracks. Each and every centre contributes to a different area of automobiles and mainly focuses on indigenous R&D.

Since the automotive sector is highly competitive and innovation-driven, any modification in the country's intellectual property (IP) regime can have major implications for the sector. Recognising the important role of a robust IP ecosystem in fostering the direction and quality of innovation, the Department for Promotion of Industry and Internal Trade (under the Ministry of Commerce and Industry), designed a National IPR Policy, which was adopted by the Union Cabinet in 2016 (Mukherjee and Chawla, 2018). Such policy and supporting initiatives, such as the amendment of the Patent Rules 2003 to streamline the process making it faster and more user-friendly, the augmentation of technical manpower handling the IP applications and the setting up of a network of technology and innovation support centres across India have opened up new opportunities for automotive manufacturers.

Just as mechanisms are needed to protect the intellectual property rights of the firms in the automotive sector, integration of business processes through Information and Communication Technologies (ICT) are equally important for the automotive sector that operates on a global level (Biethahn et al., 2013). ICTs are crucial for any sector that depends on connectivity, efficiency, use of technology and innovation and linkages within and across sectors. To support this, the government has launched initiatives such as "Make in India", "Digital India", "Startup India" and many other parallel initiatives. The government also brought in policies like the National Cyber Security Policy 2013 and the draft Internet of Things (IoT) Policy (drafted in 2015 and revised in 2016) to regulate as well as promote the ICT sector in India (Mukherjee and Chawla, 2018).

With an objective to develop programmes and policies for fostering innovation across industry sectors, the Atal Innovation Mission (AIM), a flagship initiative set up by NITI Aayog was launched to promote a culture of innovation and entrepreneurship in the country. The "Atal New India Challenge" (ANIC) is one of the sub-programmes that seeks to provide resources for piloting, testing and for market creation for new challenges/ project ideas such as the smart mobility projects that come under the aegis of the Ministry of Road Transport and Highways[7].

Dealing with aspects of logistics infrastructure and last mile connectivity, the "Pradhan Mantri Gram Sadak Yojana" (PMGSY) was launched in 2000 with the purpose of providing good all-weather road connectivity to remote villages across India so that the automotive sector can reach the hinterlands of the country. Five years later, the government announced an ambitious highway development programme, called the "Bharatmala Pariyojna", bringing a new wave of development for the sector in the form of well-maintained and developed roads and economic

7 Sourced from: https://aim.gov.in/ANIC_1.0_SSC_Selection_Summary.pdf

corridors. In addition, the AMP 2026 lays emphasis on the development of dedicated facilities for the automotive sector in several ports. It also highlights the requirement of dedicated rail links and multiple dedicated freight corridors with the capacity to facilitate the movement of freight trains. Last mile connectivity to ports and stations is equally important. Given the crucial connection between the automotive and the infrastructure sector, the government needs to adopt a holistic approach to the Indian transport sector factoring in all the modes of transport (rail, road, air and ports) instead of developing each in isolation (Kumar and Sharma, 2019).

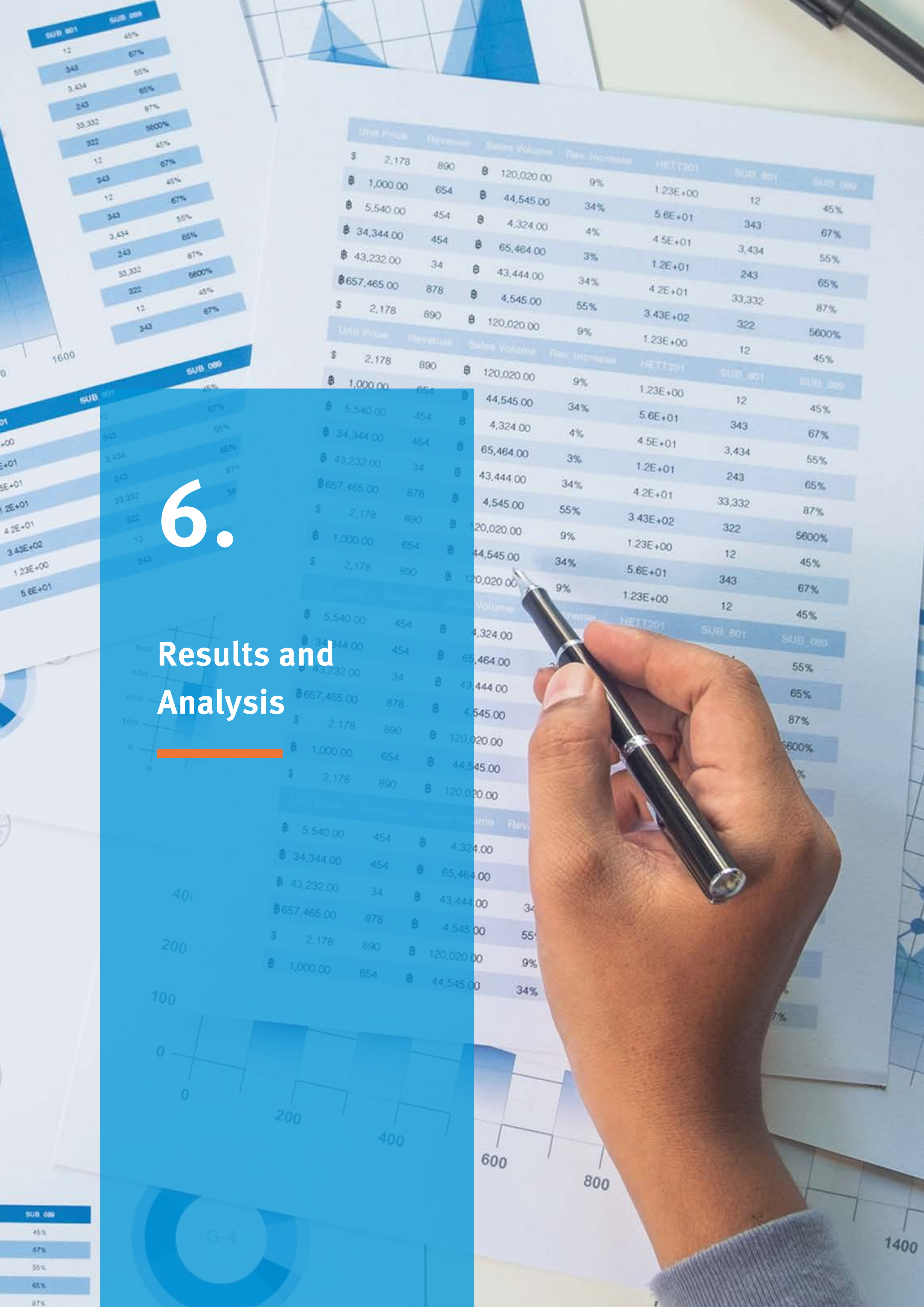
Intending a cleaner environment and wanting to lower the import dependency on fossil fuels, the "National Policy on BioFuels" (NPBF) under the Ministry of Petroleum and Natural Gas (MPNG) was approved in May 2018, which envisages a target of 20% of blending of ethanol and 5% of biodiesel in petrol and diesel, respectively by 2030 (MPNG, 2018). For providing sustainable mobility and accessibility to all citizens, the Ministry of Urban Development (MoUD) issued an updated version of its National Urban Transport Policy (NUTP) in 2014 with an (A-S-I), 'Avoid (increase in demand for travel), Shift (from personal vehicles to mass rapid transport), Improve (include clean fuels and clean technology) ' approach as advocated by the Asian Development Bank for making transport more climate-friendly (MoUD, 2014). Besides, a prescribed framework for vehicles on roads, "The Motor Vehicles Act" (1914), was amended in 2019 with regard to the issues of recall of vehicles, taxi aggregators, various offences and related penalties. It also proposes a probable development of a national transportation Policy, in consultation with state governments, among many other things[8].

Fiscal measures also play a crucial role in the performance and growth of the automotive sector. Measures such as slashing excise duty for hybrid vehicles, an increase in customs duty on imported vehicles, or provision of additional income tax deduction on the interest paid on the loans taken to purchase EVs have a huge bearing on the sector. The introduction of the Goods and Services Tax (GST) led to the overhauling of the taxation regime in India, where tax rates for commercial, used and personal cars varied. Initially EVs, the chargers and charging stations were taxed at 18%, and this was subsequently revised to 5% by the 36th GST Council Meeting held in July 2019 (post the start of FAME II) for the promotion of sustainable and green mobility[9]. The government also needs to build a supporting environment for innovation from a taxation perspective. The income tax law in India provides a weighted deduction of 200% for in-house R&D facilities and 175% on outsourced R&D from national labs or research institutions in the automotive sector. But automotive R&D is likely to take a hit due to the reduction in this allowance from 1 April 2020. Nevertheless, given the complexity of the Indian taxation system (including multiplicity of taxes), fiscal support to the automotive sector can be indispensable for its long-term growth and advancement.

To drive growth in any sector, strong linkages and synergetic effects from policy initiatives in cognate policy areas are crucial. The policies can be devised as per the applications or skills that govern the scientific progress of the sector such as research and development, along with a focus on upgrading infrastructure and increasing manufacturing power and sales. Both scholars and practitioners often link the effectiveness of policies to the need for coordination and integration (Tosun and Lang, 2013). Involvement of stakeholders in the policy-making process may also result in better policy design and more efficient policy implementation (Tosun and Lang, 2013). Ultimately, the idea is to ensure that sectoral policies get duly enacted and fulfilled in a way that ensures rapid progress and technological advancement in the sector.

8 Sourced from: http://egazette.nic.in/WriteReadData/2019/210413.pdf

9 Sourced from: https://www.paisabazaar.com/tax/gst-on-cars/



6. Results and Analysis

Results and Analysis

This chapter sets out to analyse the results of the IASSI 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 between the actors of the system. This then leads to the elucidation of the barriers that exist within the automotive 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 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 IASSI.

Characteristics of the Indian Automotive Sectorial System of Innovation Survey

The composition of the actors in the IASSI Survey has been detailed in the 'Methodology' chapter. Table 3 below shows the actor distribution and response rate.

Overall, the response rate of the survey is 29%. The highest response rate (50%) is of intermediaries represented by institutions supporting technical change and industry associations, followed by 'KBI' and 'Industry' at 39% and 27%, respectively. The 'Arbitrageur' category shows a response rate of 26%. However, there were only 2 responses from 'Government'. Out of the 11 ministries contacted, only 2 participated in the survey, which constitutes 18%.

Figure 3 below summarises the respondent distribution by actor group. The composition is 74%, 13%, 9%, 0.6% and 4% from 'Industry', 'KBI', 'Intermediary', 'Government' and 'Arbitrageur', respectively.

Figure 3: Distribution of Respondents by Actor Group

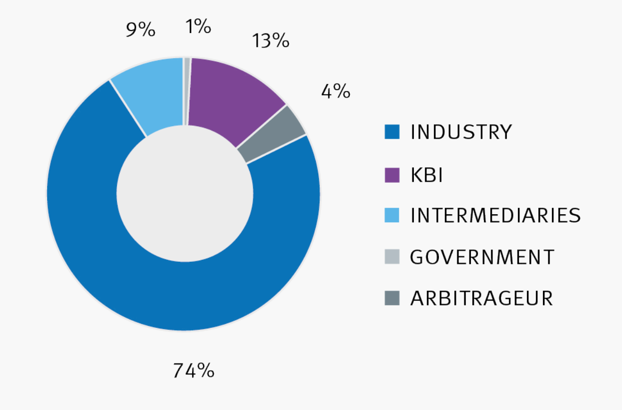


TABLE 3: Indian Automotive SSI - Universe of Respondents, Convenient Samples and Responses

Actor	Universe	Convenient Sample	Response	Response Rate (%)
Industry	1058	988	263	26.62
KBI	122	121	47	38.84
Intermediary	63	62	31	50.00
Government	11	11	2	18.18
Arbitrageur	56	54	14	25.93
Total	**1310**	**1236**	**357**	**28.88**

Figure 4. Ownership Structure of Firms

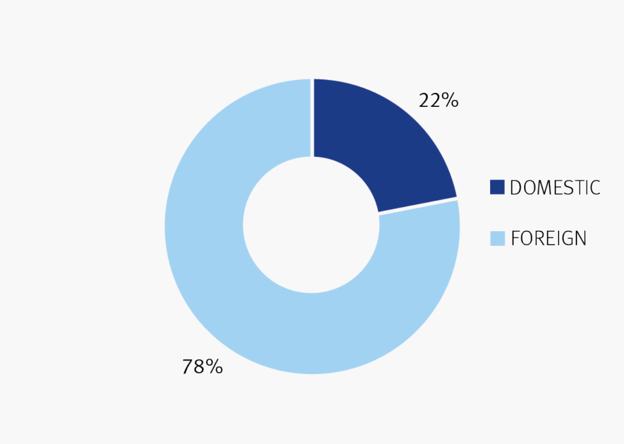
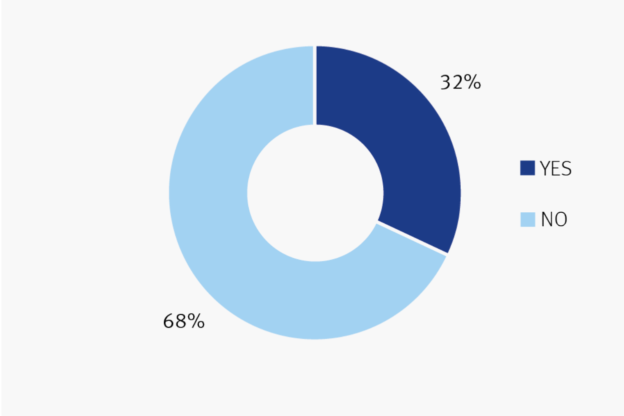


Figure 5. Familiarity with Sectorial System of Innovation



As shown in Figure 4, the majority of firms (78%) are domestically-owned, while the proportion of foreign-owned firms is 22%.

The industry actor group is made up of OEMs, tier-one, tier-two and tier-three automotive manufacturers, the majority being 'Tier- 1' manufacturers. Universities, public and private research institutes and think tanks constitute KBIs, the majority being universities. Subsequently, intermediaries are composed of ISTC and industry associations. Arbitrageurs are equally composed of angel networks and venture capitals. This is outlined in Figure 6.

It is important to get further clarity with respect to the industry actors in order to better elucidate the data in this report, particularly as the majority of innovation takes place at the firm level. Figure 7 below depicts the manufacturing activities of firms surveyed. The lion's share of firms are involved in transmission and train parts manufacturing, vehicle body manufacturing and engine manufacturing. Only a limited number of firms surveyed are involved in Industry 4.0-related production such as the manufacturing of advanced motor control systems, smart head units, telematic gateways, intelligent antennas and advanced driver assistance systems.

Figure 6: Affiliation of Respondents within Each Actor Group

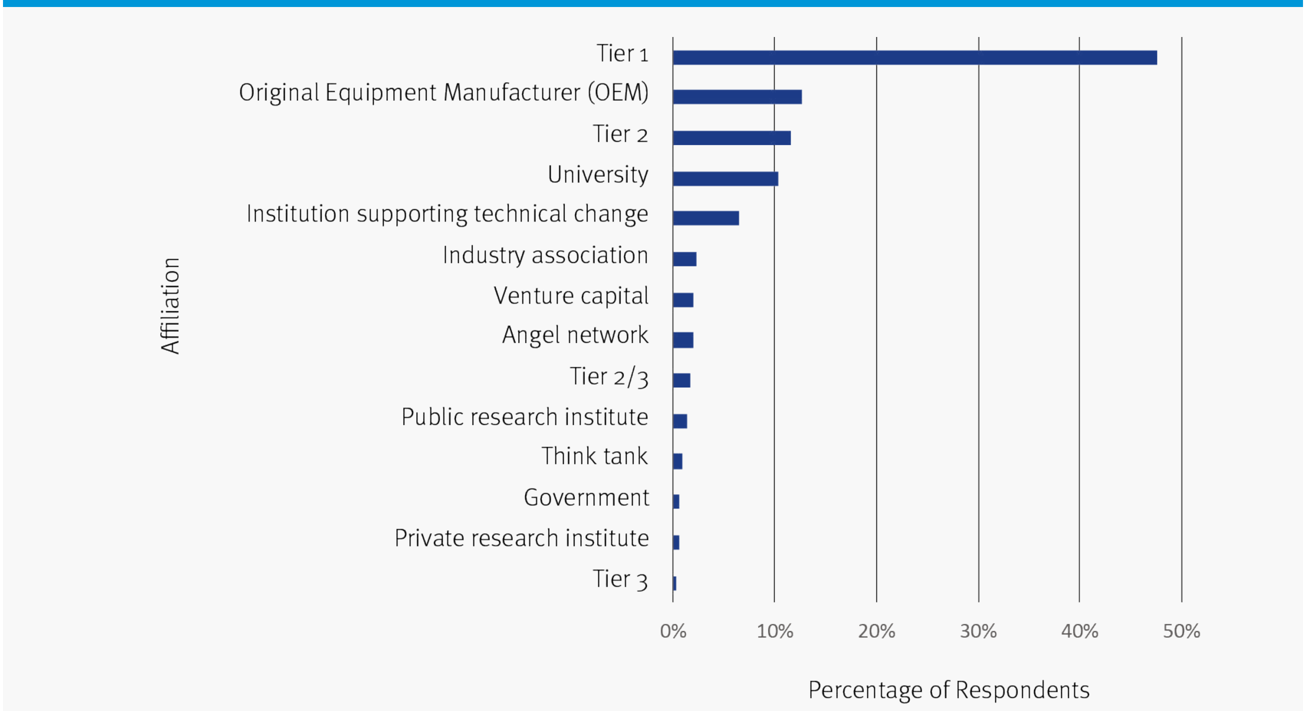


Figure 7. Manufacturing Activities of Firms Surveyed

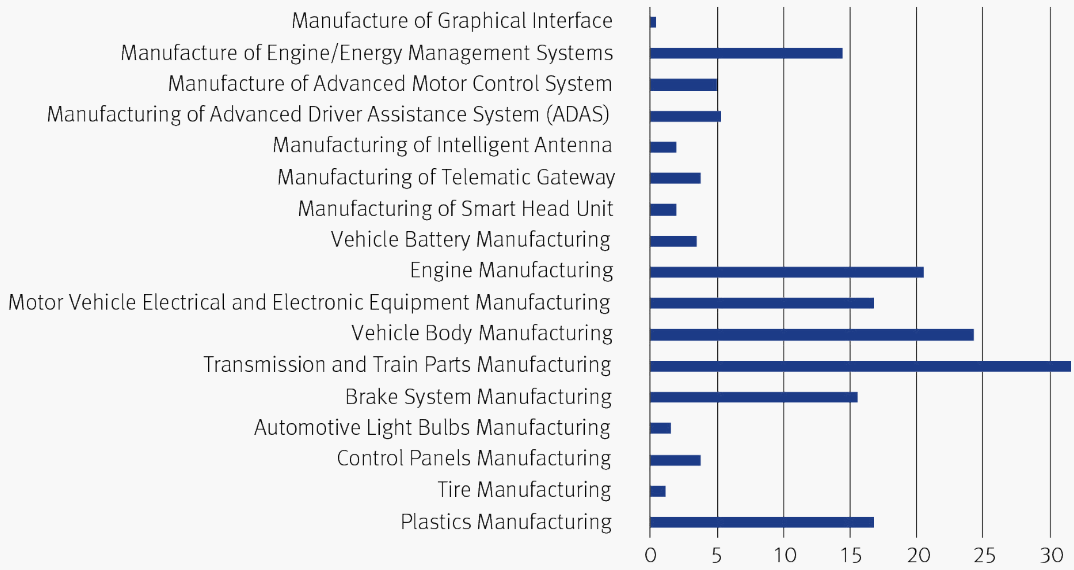


Figure 8. Regional Distribution of Respondents

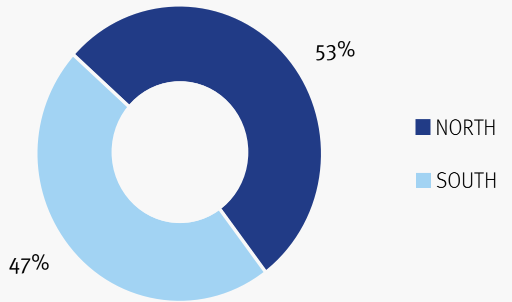


Figure 9. Regional Distribution of Respondents by Actor Group

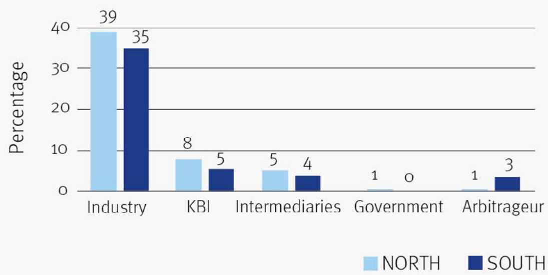


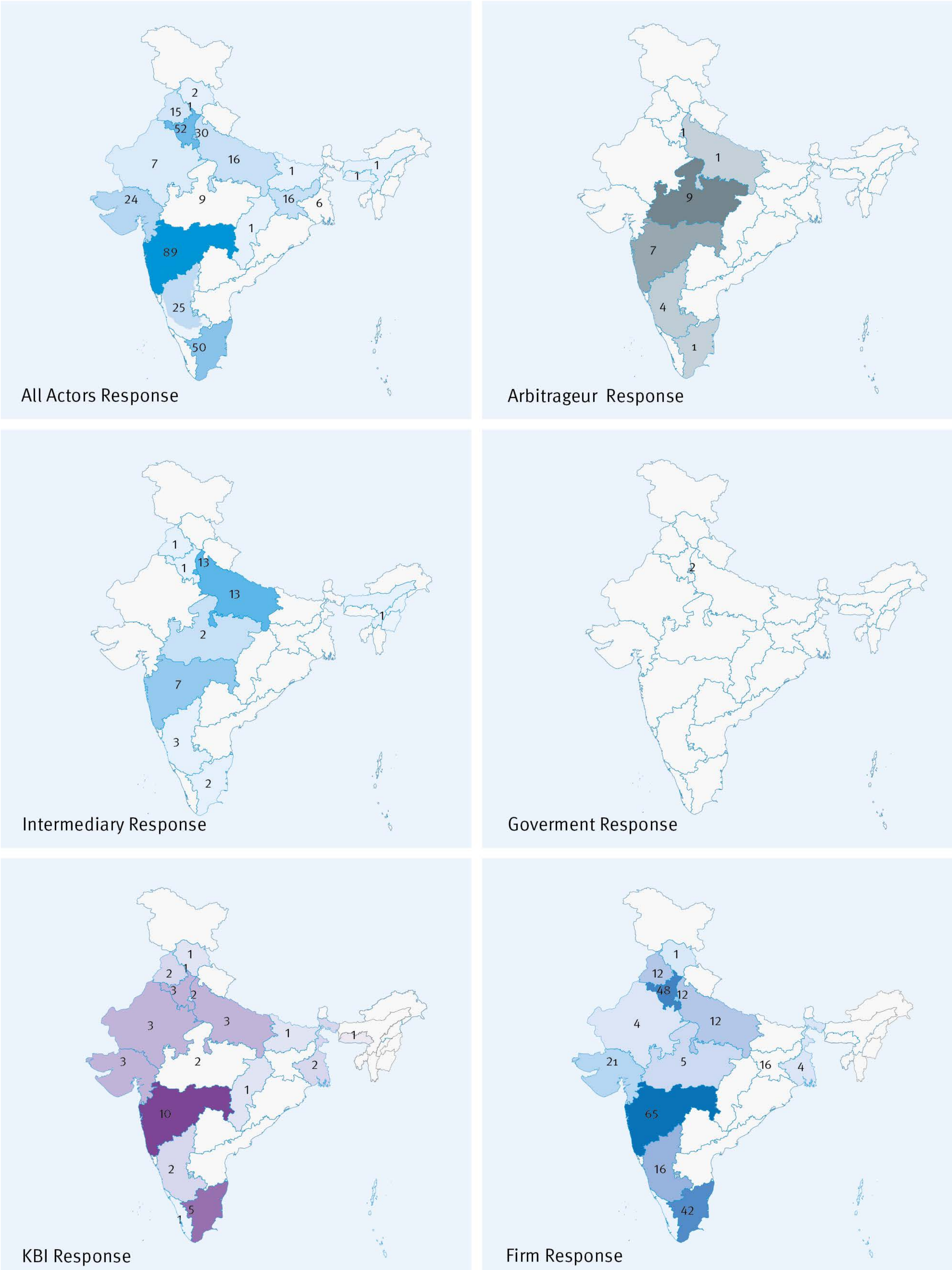
Figure 8 presents the actor distribution of respondents across North and South India, while Figure 9 further elaborates this representation across actors. It is evident that 'Industry', 'KBI' and 'Intermediary' representation is slightly higher in North India compared to South India. Government representation is located in the 'North' and the majority of arbitrageurs are located in the 'South'.

Figure 10 provides a spatial analysis of the IASSI actor respondents in terms of location density. A key dimension of the effectiveness and efficiency of a sectorial system of innovation is proximity. This translates to connectedness and linkages, and it is crucial to appreciate the spatiality of the IASSI actors, as it has implications for policy design.

Firstly, with respect to the survey sample, as is expected, the government is centralised in Delhi. Secondly, the majority of industry respondents are found in Maharashtra, Haryana and Tamil Nadu. With respect to KBI respondents, the majority are located in Maharashtra. The greatest agglomeration of intermediary respondents is in Delhi. The majority of arbitrageur respondents are found in Maharashtra and Karnataka. From an all-actor perspective, the majority of respondents are concentrated in Maharashtra, Haryana and Tamil Nadu.

Maharashtra is India's leading automobile hub with a market share of 21%. It accounts for 35% of India's automobile output by value (IBEF, 2020). Major centres of automobile production in Maharashtra are in Pune, Aurangabad, Mumbai and Nashik. The northern automotive cluster can be found in the National Capital

Figure 10. : Choropleth Maps of All Actor, Industry, KBI, Intermediary, Government and Arbitrageur Responses



Region with centres in Gurugram and Manesar in Haryana. The southern automotive cluster is located in the state of Tamil Nadu and has direct access to a major port, a large population, and strongly related and supporting industries with major industries located in Chennai (Bapat et al., 2012).

The spatial distribution of actors carries implications in terms of policy recommendations. This needs to be taken into consideration when trying to understand the challenges of innovation and hence crafting the requisite policies.

Measurement and Analysis Frame

The IASSI Survey obtained quantitative data on three dimensions of the SSI, namely: the components of the SSI; the barriers to innovation and the success of policy instruments. Actor perceptions of the SSI variables along these dimensions were measured by enabling respondents to express both the direction and strength of their expert opinion (Garland, 1991; Clason and Dormody, 1994) along five-point Likert scales, as well as through dichotomous and open questions. There is strong empirical evidence that supports the treatment of ordinal variables as conforming to interval scales (Labovitz 1967, 1970, 1971). In order to ensure the highest validity, reproducibility and reliability of the acquired data, the IASSI Survey instrument used test-retest questions (Easterby-Smith, et al., 2012). With respect to test-retest (intra-observer) reliability, this was achieved by repeating certain questions under different dimensions of the survey. This is the basis of test-retest reliability (Kitchenham and Pfieeger, 2002), which allows the consistency and significance of responses by the respondents, where possible, to be validated through statistical analysis. In terms of analytical tools, the two main approaches used are descriptive statistics, namely frequency analysis, and data reduction techniques such as factor analysis.

Figure 11. Actor Awareness of SSI

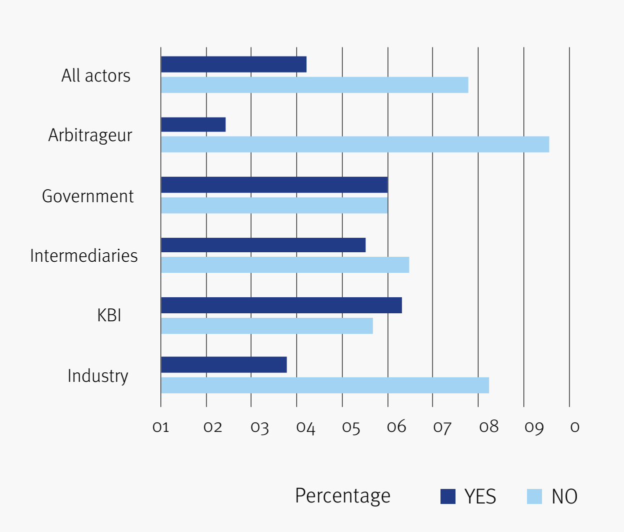
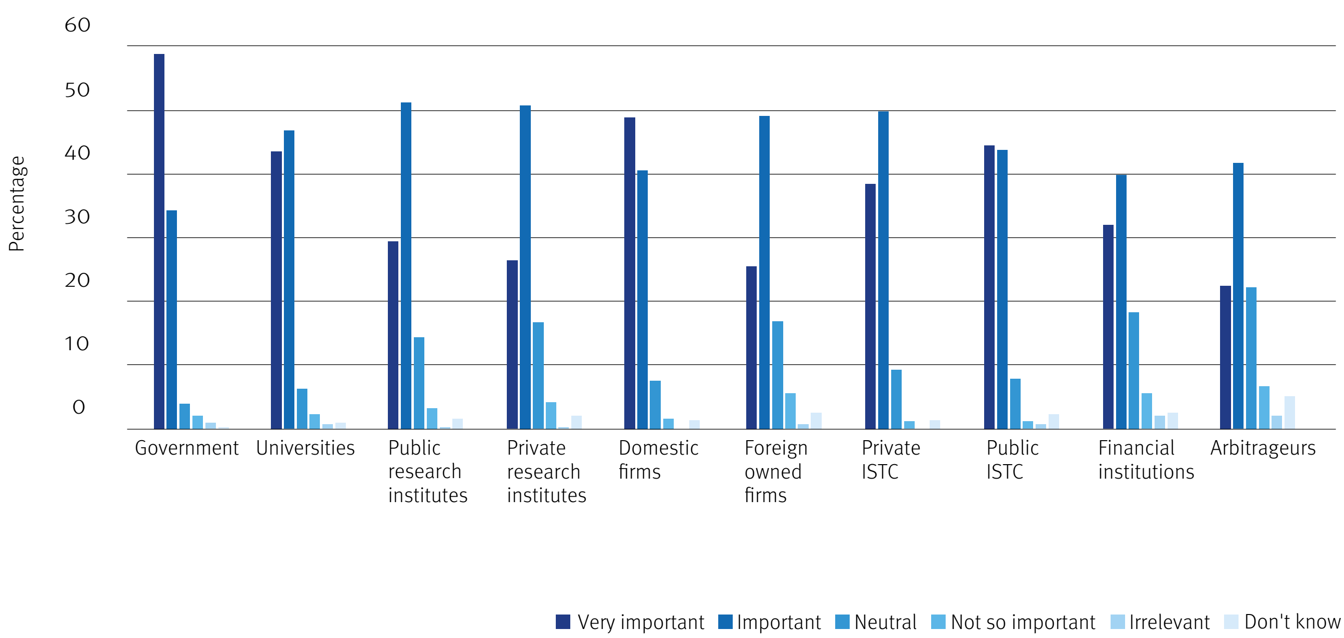


Figure 12. : Importance of Actors in SSI



Automotive SSI Survey Results

A foundation to actors interacting within the system of innovation is their awareness of each other, as well as the relative importance of each other's role within the system. It is clear from the chapter 'Theoretical Underpinnings', that each actor within the system has a specific function. A first step in understanding these relationships is to comprehend how familiar the actors are with the term 'SSI'. Is this term solely a buzzword or is there an effective understanding of what it means? Figure 11 provides a breakdown by actor and shows that amongst knowledge-based institutions the majority of respondents are aware of the term. In the case of government actors, there is a split in awareness of the term. However, it should be noted that the response rate amongst government actors is extremely low (2 respondents) for the result to be meaningful.

In the case of industry, intermediaries and arbitrageurs, the majority are unfamiliar with the term 'SSI'. It is important to note that neither may use the term in their day-to-day vocabulary, however in reality they may be functioning in the SSI framework by default. Clarity on this will be gained as further analysis is undertaken.

A frequency analysis was conducted of all the actors to gauge how important they feel the actors of the system are, as shown in Figure 12. In general, the data reflects that all actors are deemed important ('Very important' and 'Important' scoring the majority). Overall, close to 60% of respondents reported that the 'Government' is a very important actor within the SSI. This result leans towards the TH-Type II wherein the coordinating role of government is considered the prime mover of economic and social development (Etzkowitz, 2008).

Linkages

Before the issue of the linkages between the actors in the IASSI is brought to the fore, it is important to reiterate the importance of linkages from the perspective of the SI. 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 particular technologies or methods for example. 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, recipient of funding and recruitment/placement.

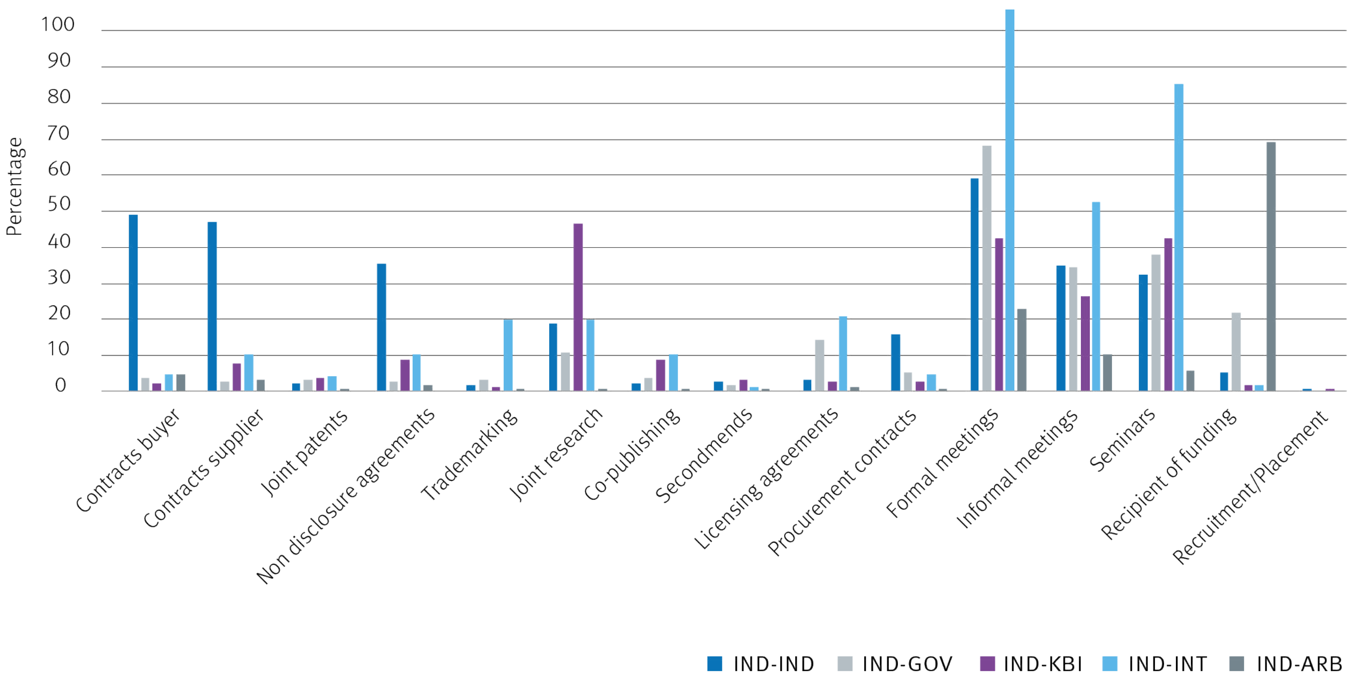
Industry

Figure 13 shows the share of industry respondents that reported one or more engagement (linkage) with system actors. The graph also depicts intra-linkages with other industry actors.

More than 50% of industry respondents do not report any type of intra-linkage with other industry actors. Close to 40% of respondents indicate contract buyer and supplier intra-relationships. Out of these 40% of respondents, the majority (64%) are tier-one companies, followed by tier-two and OEMs. Respondents reported 'Formal meetings', 'Informal meetings' and 'Seminars' as the main forms of engagement with other industry actors. It can be seen from this that there is a level of communication between industry respondents which can act as a means to exchange ideas and transfer knowledge. However, despite these channels of communication there is a low conversion into joint activities such as research that can lead to innovation.

In terms of inter-linkages, the majority of industry respondents did not report any linkages other than through 'Formal meetings' (89% with intermediaries and 57% with government), 'Informal meetings' (44% with intermediaries) and 'Recipient of funding' (58% with arbitrageurs, mainly banks).

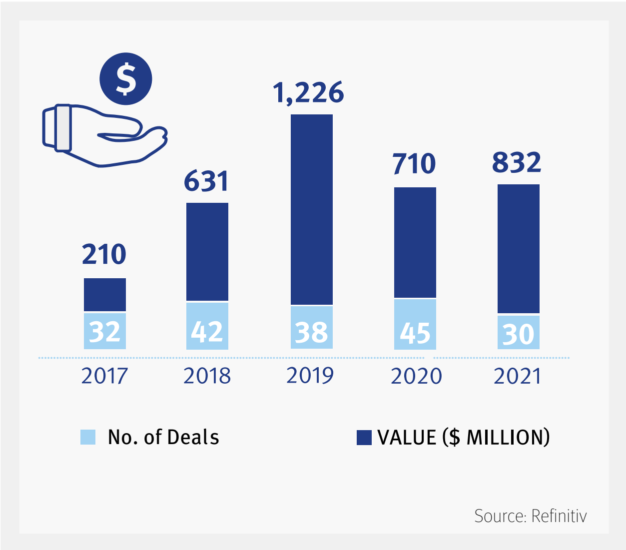
Figure 13. Share of Industry Respondents that Reported One or More Linkages



With respect to the GoI, only 18% reported receiving funds from the government which indicates poor public financing for the sector. GoI has approved several schemes for financing the automotive and auto component sector including the latest Production Linked Incentive (PLI) scheme worth Rs 25,938 crore. According to the scheme, existing auto manufacturers will have to make new investments of Rs 1,000 crore over the next five years and new players will have to invest over Rs 2,000 crore. In the auto component sector, existing companies will have to invest Rs 250 crore and new players will have to invest Rs 500 crore (ET Online, 2021). As of January 2022, 115 firms have applied for the scheme, out of which 20 are OEMs, 83 are component manufacturers, 9 are new non-automotive (OEM) investor companies and 3 are new non-automotive (component) investor companies. Incentives are available for the sales of Advanced Automotive Technology (AAT) products (vehicles and components) manufactured in India from 1st April 2022 for 5 consecutive years. This would mean that the majority (80%) of India's automotive sector will not benefit from the scheme. The PLI scheme, while a positive and futuristic initiative, will mostly serve just 10% of the current Indian vehicle market at least for the next 2-3 years and at most 20-25% of the market during the 5-year period of the scheme (Khan, 2021).

With respect to KBIs, 38% reported linkages through 'Joint research', 35% through 'Formal meetings' and 'Seminars' and 22% through 'Informal meetings'. However, only 1% of industry respondents indicated 'Recruitment' or 'Secondment' relationships with KBIs. Formal and informal engagement with KBIs needs to translate into the absorption, by industry, of skilled human capital leading to job creation.

As expected, 90% of industry respondents reported linkages through 'Formal meetings' with intermediaries (industry associations and ISTCs). These formal meetings mainly include those of industry associations with their members. For instance, the Automotive Component Manufacturers Association of India (ACMA) is the apex body representing the interest of the Indian auto component industry with a membership of over 850 manufacturers that contributes to more than 85% of the auto component industry's turnover (ACMA, 2021). The Society of Indian Automobile Manufacturers (SIAM) has a membership of 40 auto manufacturers. ACMA meets with its executive committee members approximately every two months and holds an annual general meeting, whilst SIAM meets 3-4 times a year. Additionally, manufacturers also interact formally with ISTCs for, amongst other things, patent approvals,

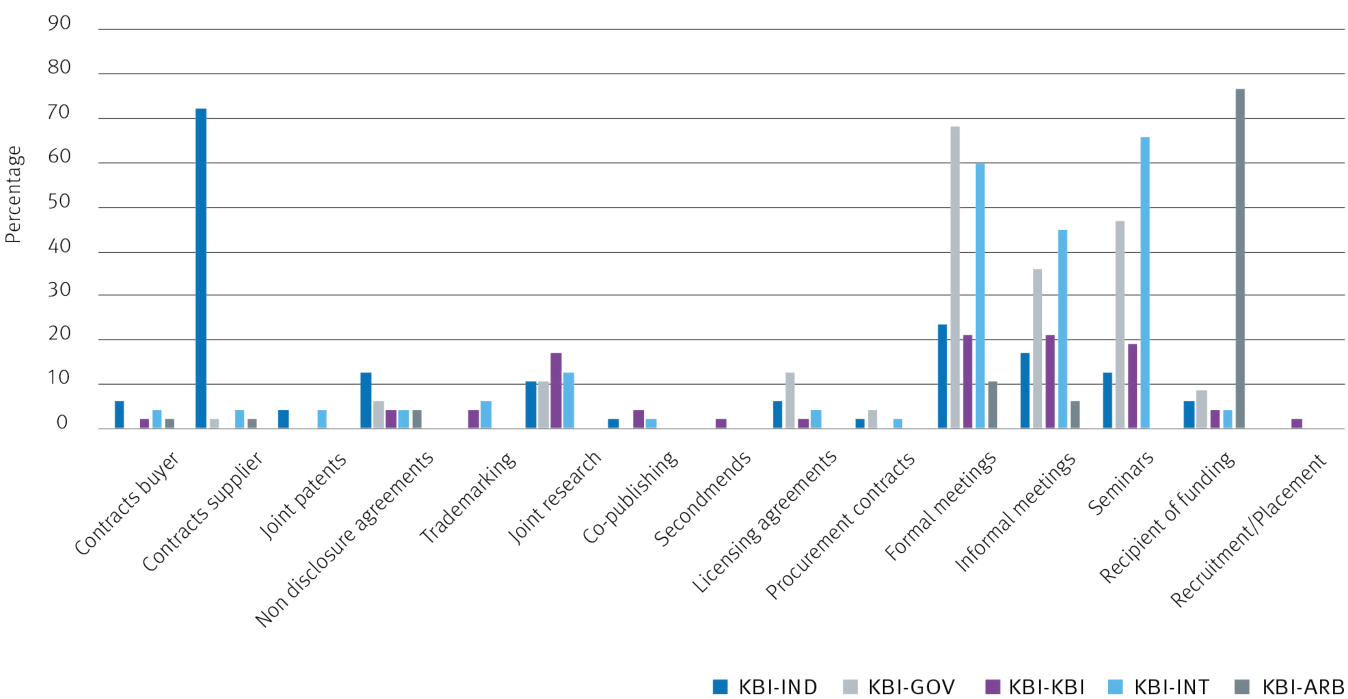


standards certifications and factory inspections.

With respect to arbitrageurs (banks and venture capitalists), the majority of firms (58%) reported relationships as 'Recipients of funding'. Given the type of respondents (mainly tier-one, OEMs and tier-two companies), the majority of funds come from banks rather than venture capital. However, automotive startups received over USD 800 million from investors in 2021. A strong investment traction in startups is visible since 2019 from venture capital funds such as Sequoia Capital and Accel, and by auto companies such as Hyundai and Kia (Rao, 2019).

It is to be noted that only less than 20% of industry respondents report the following linkages with other actors: 'Joint patents' which could foster cost-sharing R&D alliances (Sakakibara, 1997) and informal and open idea exchange (Slowinski & Sagal, 2006); trademarking[10] which helps manufacturers appropriate the economic rents from innovation (Seip et.al, 2018; Castaldi et. al, 2020); 'Joint research' (except 39% with KBIs) to reduce costs, minimise risks, promote knowledge and technology transfer and improve market access (Edwards-Schachter et. al, 2012); 'Co-publishing' that facilitates knowledge and information flows, networking, collaboration and better knowledge dissemination (OECD, 1997); 'Secondments' and 'Recruitment' for the tacit flow of knowledge (Lincoln & Ahmadjian, 2000) between system actors, experiential and relational learning as well as organizational development (Renshaw & Holland, 2013); 'Licensing agreements' for rent generation and technology transfer (Boger et. al, 2012) and 'Procurement contracts', especially for tapping into supplier innovation (Bernstein, 2015).

Figure 14. Share of KBI Respondents that Reported One or More Linkages



10 Manufacturers register for trademarks with the government through the trademarks registry at E-Register - Main Page: Sourced from: ipindiaonline.gov.in

Knowledge-based institution

Figure 14 shows the share of KBI respondents that reported one or more engagement (linkage) with system actors including other KBIs.

A majority of KBIs do not report any intra-linkages. 'Joint research' with other KBIs is reported to be as little as 17% of respondents, 'Formal meetings' and 'Informal meetings' by 21%, 'Seminars' by 19% and 'Recruitment' activities by 2%. This suggests there is much room for improvement in terms of knowledge exchange and cooperation between KBIs working in the automotive sector. The low reporting on 'Formal meetings', 'Informal meetings' and 'Seminars' may also be due to the impact of COVID-19 and related restrictions during the phase of transition from offline to online modes of engagement.

Collaborations between universities, and public and private research institutions are excellent sources of research data. Therefore, its successful management can generate firm-level benefits leading to innovative ideas and impulses and the provision of support for technological development (Steel et al., 2018 and Broström & Mckelvey, 2015). Consequently, it is crucial that intra-linkages between KBIs are strengthened to result in the bolstering of direct support to industry.

With respect to industry, it is interesting to note that more than 70% of KBI respondents reported that their organizations act as contract suppliers. This may be in the form of knowledge intensive services such as contracted research, consultancy and technical services that play a major role in the creation and commercialisation of new products (goods and services) and business processes by firms (Tether & Tajar, 2008).

KBIs interact with the government through 'Formal meetings' (68%), 'Seminars' (47%) and 'Informal meetings' (36%). 'Joint research' with the government was only reported by 11% of KBIs, and linkages as 'Recipient of funding' from government by only 9%.

With respect to intermediaries, the majority of respondents indicate engagement through 'Seminars' (66%), 'Formal meetings' (60%) and 'Informal meetings' (45%). As with the government, few (13%) respondents indicated 'Joint research' activities with intermediaries.

With respect to arbitrageurs, 77% of KBIs reported that they receive funds. This result is a signal that the process of ideation to market is encouraged, given that arbitrageurs are the dominant source of commercialising risky new ideas and technologies (Lerner and Nanda, 2020).

However, the majority of KBIs do not interact with other actors through 'Joint patents' which could generate rents from research activities; 'Joint research' for idea generation; 'Co-publishing' for codification of knowledge and its dissemination for uptake by other system actors (knowledge diffusion); 'Secondments' and 'Recruitment' for the tacit exchange of knowledge; 'Licensing agreements' for rent generation and boosting technology transfer and triangulation with other actors to participate in procurement contracts (Etzkowitz, 2017; Etzkowitz and Leydesdorff, 2000; Etzkowitz et al., 2000).

Intermediary

Figure 15 shows the share of intermediary respondents that reported one or more linkages with system actors including other intermediaries.

Regular formal communication between intermediaries is evident given that all respondents reported intra-linkages in the form of 'Formal meetings'. 81% also reported intra-linkages through 'Seminars' and 48% in the form of 'Informal meetings'. However, intra-linkages in terms of 'Joint research' were reported by only 10% intermediaries and 'Co-publishing' by 6%. The lion's share of research papers and reports published by industry associations are generally produced with international consultancies such as Ernst & Young, McKinsey, Deloitte, etc. This highlights the scope for 'Joint research' activities and their reporting between intermediaries themselves.

There are very few intermediaries engaged in such joint research activities in the automotive sector. However, ARAI[11] along with SIAM, OEMs and IOCL as per the directions of NITI Aayog and under the support of DST is working on a project to evaluate the performance of M15 fuel on gasoline using 2 and 4-wheelers. The outcome of the study will show the effect of M15 fuel on tail pipe emissions, evaporative emissions, drivability and engine/vehicle durability on identified vehicles. These results will be an input for taking forward the implementation of M15 fuel in automotive applications.

With respect to industry, it is interesting to note that 42% of intermediaries have linkages with industry as 'Contract buyers' and suppliers, 48% through

11 The research programmes at ARAI are focussed on different automotive engineering domains such as safety, powertrain, lightweighting, alternate fuels, electric vehicles and simulation.

BOX 4: Academia-Industry Linkages - IIT Delhi

Objective:

IIT Delhi, a premier technical university in India strives to achieve excellence in scientific and technical education and research and works for the development of human capital that can serve as a valuable resource for industry and society.

Approach:

IIT Delhi lays a strong emphasis on sponsored research and industry interaction as active collaborations with industries across the globe. Some of the engagement activities in the automotive sector are:

- M.Tech course in Electric Mobility for which sponsored candidates from the industry are encouraged to apply.
- In 2019, it established the Centre for Automotive Research and Tribology (CART) to carry out cutting-edge research in the areas of battery-operated electric vehicles, hybrid electric vehicles, storage and alternate energy sources, and autonomous and connected vehicles.
- CART has collaborated with various research labs and automotive industries such as MG Motor India, Hyundai Motor India Foundation, Nanotechnology startup and Log9 Materials.
- **Collaboration with MG Motor India:**
    - In 2021, MG Motor India partnered with CART for ground-breaking research in the field of electric and autonomous vehicles.
    - The ongoing research areas include: Connected Mobility for Route Planning and Navigation, Obstacle Detection, Seamless and Natural Human Interaction, and AI for Inferring and Decision-making.
    - Through its partnership with the institute, MG Motor is looking to provide a platform for students and startups to develop technologies and features for its upcoming cars that will be produced in India.
    - The company has also donated its ZS EV vehicle to IIT Delhi for conducting research on the deployment of electric and autonomous vehicles in the urban landscape in India.
    - Completed project: 'In-child safety app' - MG Motor started its engagement with IIT Delhi in 2018 with a yearlong project to boost in-car child safety seats through geofencing. They have developed an application for geofencing for child safety through ECU control that will enable owners of upcoming MG cars in India to track and alert the whereabouts of their children while travelling in a car, including their entry and exit as well as their seating position in the vehicle. It will also alert users if the car is driven beyond a pre-defined route map.

Challenges:

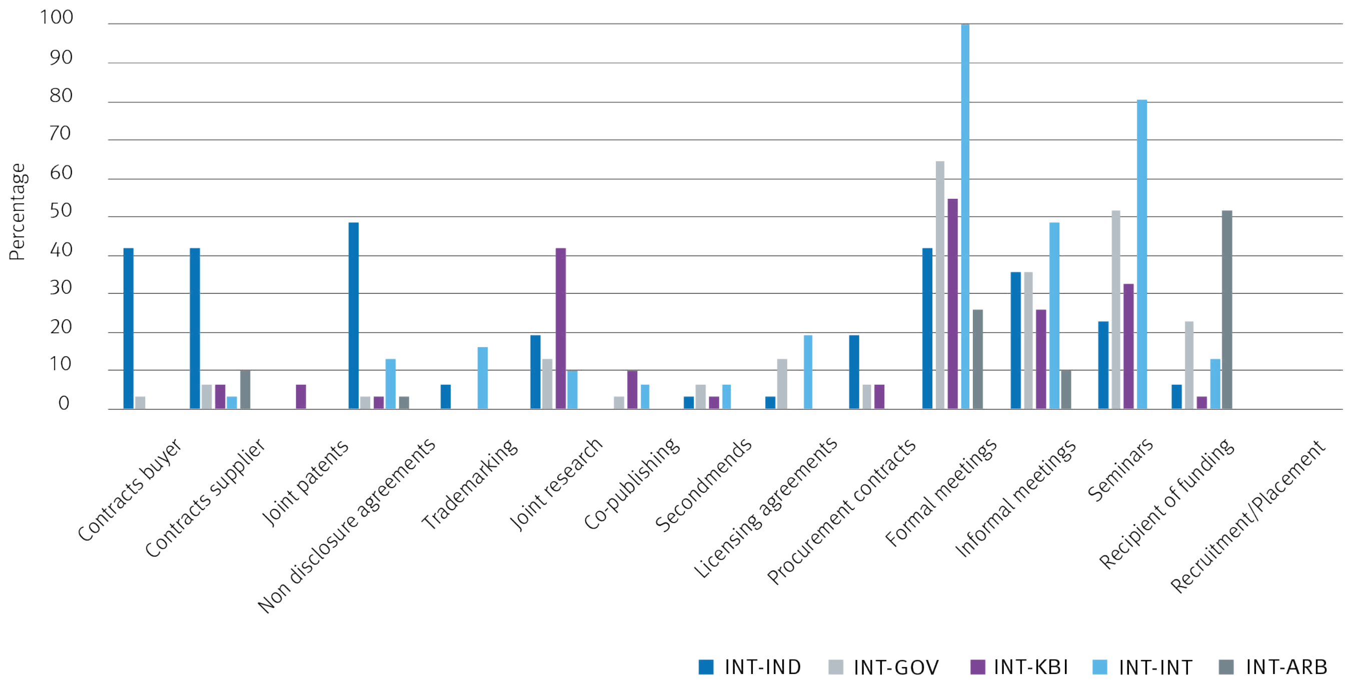
- All machines and batteries for EVs are imported but government purchase rules and a complicated global tender enquiry (GTE) system make it difficult to access those machines and technologies for the research and development of EVs in India.
- Moreover, the commercialisation of research outcomes requires time, huge investment and support from the government which is lacking in India.

Outcomes:

- Industry collaborations are helping students to study alternate energy powered vehicles and emerging technologies to create new-age mobility solutions.
- As for the industry, such collaborations are ensuring the matching of skills supply to the needs of the industry.

In addition, the industry aims to use this research for developing its future autonomous vehicles.

Figure 15. Share of Intermediary Respondents that Reported One or More Linkages



'Non-disclosure agreements' and 42% through 'Formal meetings'. Intermediaries report linkages with industry through 'Joint research' (19%) and 'Co-publishing' (0%). This can be verified by previous results reported by industry with respect to their engagement with intermediaries.

A reported, 65% of intermediaries noted having linkages with the government through 'Formal meetings', 52% through 'Seminars' and 35% through 'Informal meetings'. With respect to intermediaries such as ISTCs, (e.g. the National Productivity Council, Technology Information Forecasting and Assessment Council (TIFAC) and NATRiP), who were set up and funded by the government, linkages with government are expected more so than industry associations who act as mediators and conduits for information flow between industry and the government but are mainly funded by industry.[12]

Government funding was reported by 23% of intermediaries while 'Joint research' and 'Co-publishing' were reported by 13% and 3% of respondents, respectively. Conversely, an example of a government funded initiative with an intermediary is the technology innovation platform – TechNovuus. TechNovuus, a technology innovation platform was established under the aegis of the Ministry of Heavy Industries (MHI), by ARAI as a collaborative ecosystem for enabling indigenous technology, innovation and solution development focused towards Indian mobility CASE (Connected & Shared, Affordable, Safe, Environment friendly & towards Energy Independence). The platform has initiated a programme called "UpTech" which provides technology up-levelling support to startups, MSMEs and innovators. In addition, within the framework of TechNovuus, a mobility hackathon was launched with 10 problem statements with the theme of 'Safe, Sustainable, and Smart mobility solutions' for Aatmanirbhar Bharat.

In the case of interaction with KBIs, 55% engage through 'Formal meetings', 42% through 'Joint research' and 32% through 'Seminars'. The formal and informal route of communication highlights that there is a level of knowledge exchange between the two actor groups. However, with respect to 'Joint research', contrary to the 42% reported by intermediaries, only 13% of KBIs report the same. A number of factors affect how relationships are fostered between these two actors, namely location (Bodas Freitas et al, 2014), institutional reputation and contractual safeguards (Hemmert et al. 2014). These factors generate mutual trust by reducing uncertainty and thus promote collaboration. Within the context of

12 This can be seen in pillar 2 (Government affairs and strategic initiatives) of ACMA activities. The Automotive Component Manufacturers Association of India - ACMA.

the Indian automotive SSI, this is an area for potential improvement.

In addition, 52% of intermediaries reported they receive funds from arbitrageurs. This result proves to be an outlier and further clarification is required. However, in the context of the Indian Automotive SSI this could take the form of collaborative platforms or initiatives which act as a conduit for facilitating the development of advanced technology solutions and facilitating access to startup and angel funding. Examples of these include the six technology platforms developed by IIT Madras, the Central Manufacturing Technology Institute (CMTI), the International Centre for Automotive Technology (iCAT), the Automotive Research Association of India (ARAI), BHEL and HMT under the aegis of the Ministry of Heavy Industries.

However, from the perspective of intermediary respondents with their crucial role as facilitators and enablers at the interface of system actors (Letaba, 2019), the following relationships need to be bolstered: 'Joint research' with a view of reporting the current state of affairs within the sector and its successful dissemination ('Co-publishing'); transferring tacit skills through 'Secondments'; facilitating the transfer of requisite technologies ('Licensing agreements'); and acting to cascade information with respect to sustainable procurement processes throughout the supply network ('Procurement contracts') (Veronica, 2019).

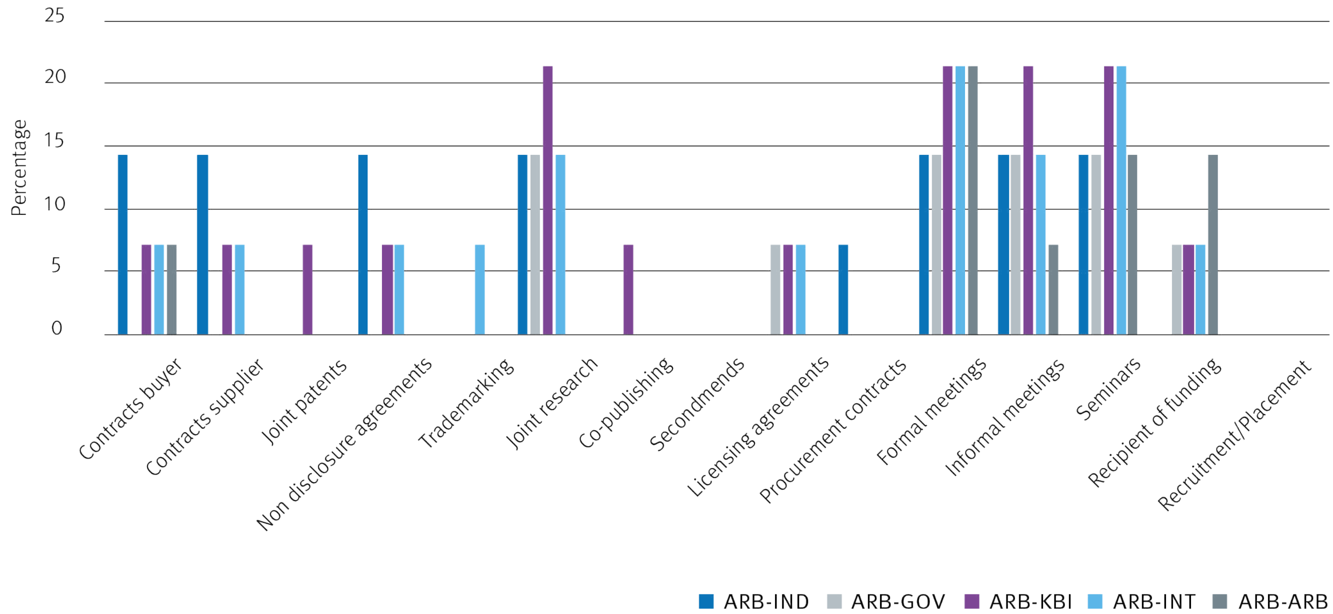
Arbitrageur

Out of the 14 arbitrageur respondents, only 3 of them responded to the question on linkages. In terms of intra-linkages, only 21% reported interactions through 'Formal meetings', 14% through 'Seminars' and as 'Recipients of funding', and 7% through 'Informal meetings'.

This indicates the low inter-connectedness between arbitrageurs (banks and VCs). Overall, less than 25% arbitrageurs have reported any type of linkage with themselves or other actors. While 21% have indicated relationships with KBIs through 'Joint research', 'Formal meetings', 'Informal meetings' and 'Seminars', 21% of arbitrageurs have also reported linkages with intermediaries in the form of 'Formal meetings' and 'Seminars'.

The few intra- and inter-linkages reported by arbitrageurs indicates their relative isolation from other actors in the SSI. As discussed earlier, without regular communication between themselves and with other actors, especially industry, arbitrageurs' understanding of the dynamics of new technologies and innovations being adopted is truncated. Consequently, the nature of investments, risks and returns would depend on how well they interact with system actors and extract the pertinent knowledge and information.

Figure 16. Share of Arbitrageur Respondents that Reported One or More Linkages



7.

Barriers to Innovation

Barriers to Innovation

Industry

In reporting the perceptions of what industry actors consider barriers to innovation it is clear that the majority of respondents indicate all barriers as constraints to innovation (see Figure 18). Nevertheless, four key groupings emerge from the results, namely: **policy, technology infrastructure, finance** and **human resources.** The prominent associated variables (reported by more than 85% of respondents) are reported below.

Firstly, with reference to **policy**, 'Lack of clear national innovation strategy' is considered a high constraint by 92.0% of respondents and 'Lack of explicit policy support' is reported by 88.2% of respondents. Secondly, related to **technology infrastructure,** 'Lack of technology (technology gap)' and 'Lack of infrastructure for I4.0' are considered constraints by 90.5% and 86.3% of respondents, respectively. Thirdly, in the context of **finance,** 'Innovation costs (too high)', 'Lack of finance', 'Excessive perceived economic risk' and 'Cost of I4.0 technologies' are indicated as barriers to innovation by 90.1%, 89.7%, 89.0% and 87.5% of respondents, respectively. Finally, with respect to **human resources**, 'Quality of technically trained manpower' is considered a constraint by 88.2% of respondents.

Despite the automotive sector's significant contributions to India's growth and employment generation,[13] industry leaders have raised concerns over the industry's decline and the lack of concrete action by the government (Bhargava, 2021). When considering the grouping **policy**, Figure 13 shows the presence of channels of communication between industry and government in terms of 'Formal meetings' (reported by 57% of industry respondents), 'Seminars' (32%) and 'Informal meetings' (29%).

However, the policy barriers 'Lack of clear national innovation strategy' and 'Lack of explicit policy support' signalled by industry actors raise the question of what is being communicated through these channels. Phrased differently, this indicates that industry feels there is no clear and comprehensive strategy guiding innovation specifically for the automotive sector. There is the existence of the "Automotive Mission Plan (AMP) 2016-26" and the "National Electric Mobility Mission Plan 2020", however, these are more of vision statements than strategies.

This is exemplified by the case of environmentally friendly electric vehicles (EVs), where there are concerns about the distribution of liability and issues of privacy. India needs dedicated policy guidelines for safety assurance systems and a well-designed plan for operations of EVs. Use of large chunks of personal data for EV operations makes data protection under privacy laws imperative (Patra, 2021). Moreover, new emission and safety norms, insurance charges, and the rise in material costs have resulted in an increase in the price of automobiles. High taxation and rising fuel costs have also affected customer affordability. The industry has called for the lowering of taxes as their key demand. For example, the most basic mode of transportation in India, two-wheelers, are being taxed at 28% GST, like a luxury product. Policy on taxation and regulations on emission and safety norms should recognise the automotive sector's contribution to employment generation, revenues and earnings of foreign exchange (Bhargava, 2021).

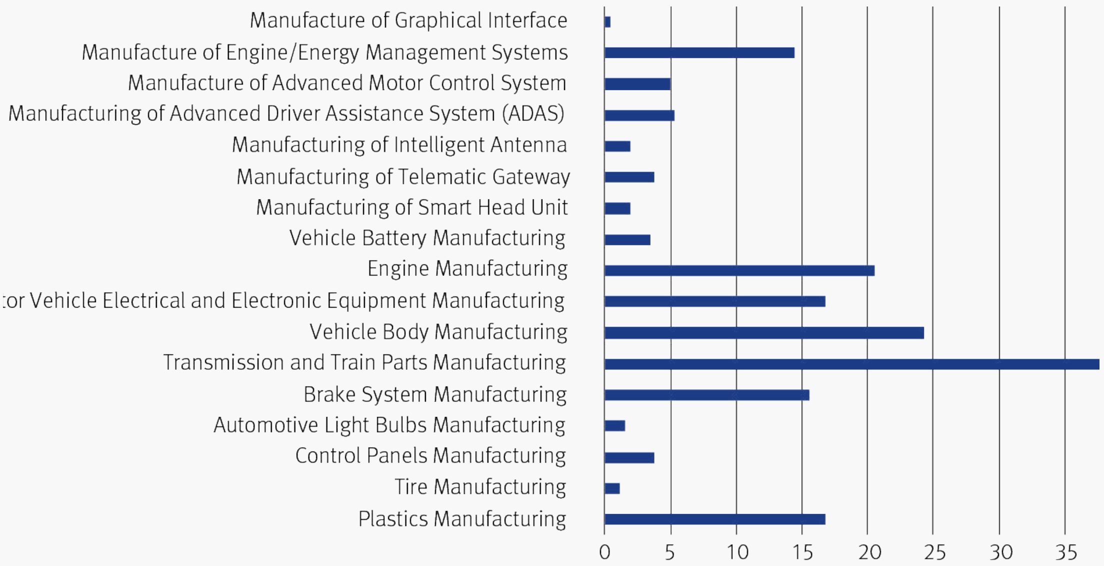
It needs to be highlighted that innovation is not the purview of one ministry alone and that it is an all of government approach.[14] To this end, there is the requirement for better coordination of information between ministries and coherent outreach to industry using industry associations as a conduit. The ministries (of Education, Finance, Heavy Industry, MSME, Environment, etc.) should work in coordination to design a national innovation strategy and policy for the automotive sector.

In the context of **technology infrastructure**, 'lack of technology (technology gap)' and 'lack of infrastructure for I4.0' emerge as the key barriers. "As technology is an

13 The automobile industry in India contributes 7.1%to the country's GDP and around 49% to India's manufacturing GDP as of 2019. It became the fifth-largest auto market in 2019 with sales reaching 3.81 million units. The automobile industry is one of the largest employment providers and employs close to 29 million people across the country. Source:https://auto.economictimes.indiatimes.com/news/industry/govt-must-support-indias-manufacturing-sector/78912329

14 Different ministries deal with diverse aspects of innovation.

Figure 17. Manufacturing Activities of Firms Surveyed



example of embodied knowledge, its absence will impact the innovation process" (Bozeman, 2000, p. 632). One such example is the 4IR basket of technologies, which drive innovation by making manufacturing more agile, flexible and responsive to customer needs. In specific terms, business processes and product innovation (Giovanni & Cariola, 2020) have been boosted through the adoption of robotics, automated guided vehicles (AGV), 3D printing, smart sensors, industrial Internet of Things, and advanced human-machine interface (Ivanov, Dolgui, & Sokolov, 2019).

However, on reflection of the data from the survey (see Figure 17), very few firms are engaged in smart manufacturing. Less than 50 out of the 263 surveyed firms were into the manufacturing of advanced motor control systems, advanced driver assistance systems, intelligent antennas, telematic gateways and smart head units.

In order to effectively make use of I4.0 technologies the requisite infrastructure is required, in particular the digital connectivity to enable the application of I4.0 technologies in manufacturing. Digital connectivity is key for the manufacturing innovation ecosystem to thrive. India's digital divide remains a challenge as more than 400 million people don't have access to the internet. Also, the spatial digital divide is huge (internet density in rural areas is lower than in urban areas) (Ghani & Mishra, 2020). The importance and impact of connectivity and digital access was evidenced during the COVID-19 pandemic, where quick digital adoption taught firms to seamlessly work and operate efficiently by exploring use of technologies like AI/ML (artificial intelligence/ machine learning), cloud computing, additive manufacturing, IoT, blockchain and robotics, to name a few.

A comprehensive ICT ecosystem using 4IR technologies across original design manufacturing (ODM), original equipment manufacturing (OEM), assembly and testing, ensuring an integrated supply chain and local talent pool is required to accelerate innovation and timely and quality production. The Government of India (GoI) Production-Linked Incentive (PLI) scheme that encompasses electronic and technology products along with sectors like battery manufacturing, automobiles and auto components, as well as telecom and networking products is a step in the right direction. To remain relevant in the 4IR ecosystem, automotive companies have to clear some near-term hurdles and have an integrated approach toward technology and innovation.

With respect to finance, 'Innovation costs (too high)', 'Lack of finance', 'Excessive perceived economic risk' and 'Cost of I4.0 technologies' are major constraints reported by industry respondents. Industry's relationship with government, KBIs and intermediaries as recipients of funding is negligible. However, the majority of funds for industry come from financial institutions which make up arbitrageurs, as seen in Figure 13.

Investments in I4.0 technologies are cost intensive (Gajdzik et al. 2021). Building the factory of the future and having an entirely connected system could require significant capital outlay. Getting access to digital technologies for MSMEs, that forms the base of the Indian manufacturing sector, remains a challenge due to the high cost of these technologies (Jadhav & Mahadeokar, 2019). The I4.0 technologies may increase the organization's overall costs during its adoption, (Luthra et. al, 2019) however, it is clear that the overall performance of the business in terms of economic gains will be improved in the long run (Hermann et al., 2016).

R&D, apart from being a risky activity, requires huge resources. Investment in R&D is especially a challenge for SMEs who tend to have lower risk-taking capabilities. For example, many global automotive OEMs ask their tier-one suppliers to sign joint product liability clauses. Like vehicle producers, auto component manufacturers fall into the high-risk category of product liabilities (Pradhan & Singh, 2009). The challenges of cost are recognised by the Government of India who in the Automotive Mission Plan (AMP) 2006-2016 recommend setting up of a technology modernisation fund, with special emphasis on SMEs. In addition to this, despite the challenges highlighted in the 'Linkages' chapter, the "PLI Scheme for the auto sector envisages to overcome the cost disabilities of the industry for manufacture of advanced automotive technology products in India. The incentive structure will encourage industry to make fresh investments for indigenous global supply chains of advanced automotive technology products. It is estimated that over a period of five years, the PLI Scheme for the Automobile and Auto Components Industry will lead to fresh investments of over Rs. 42,500 crores, incremental production of over Rs. 2.3 lakh crore and will create additional employment opportunities of over 7.5 lakh jobs. Furthermore, this will increase India's share in [the] global automotive trade" (PIB 2021).

With reference to human resources, only 1% of industry respondents have reported linkages with KBIs or any other actor in terms of 'Recruitment' and 'Secondments' (see Figure 13). This supports industry's indication that the 'Quality of technically trained manpower' is a crucial barrier to innovation. In the context of human resources, a workforce that is technically trained, and to a sufficient level of quality as per industry standards, is required for effective innovation and successful I4.0 technology diffusion. Being cognizant of the unprecedented and prolonged slowdown that the automotive industry is facing (Narasimhan, 2021), there also exists a skilled worker gap, with the challenging task of filling approximately 41.5 million positions between 2019-2025 (MHIngra, 2020). There is a projected demand of 10.91 million jobs in OEMs and auto components by 2025 (see Table 4). Currently, these sub-sectors also need the additional employment and replacement of 9.07 million workers (see Table 5).

Overall, continuous training, reskilling and upskilling of the workforce is absolutely imperative when it comes to ensuring that the 19-million workforce employed by the Indian automotive industry have the requisite skills in a new age of connectivity, big data and automation.

Knowledge-based institutions

From the perspective of knowledge-based institutions (see Figure 19), the results show that in general all variables are perceived to be barriers to innovation. However, looking at variables reported by more than

TABLE 4: Projected Workforce Demand in the Auto Sector (in millions)

Sub sector	2018	2019	2020	2021	2022	2023	2024	2025
OEM	3	3,07	3,23	3,33	3,49	3,67	3,92	4,26
Auto component	3,81	4,13	4,47	4,84	5,24	5,67	6,14	6,65
Dealership sales	3	3,04	2,94	2,95	3,03	3,12	3,27	3,47
Dealership services	2	2,02	1,96	1,97	2,02	2,08	2,18	2,31
Roadside mechanics	1,13	1,14	1,1	1,11	1,14	1,17	1,22	1,3
Dealership total	6,13	6,2	6	6,03	6,18	6,37	6,67	7,09
Drive demand	4,69	5,71	6,8	7,96	9,23	10,62	12,13	13,8

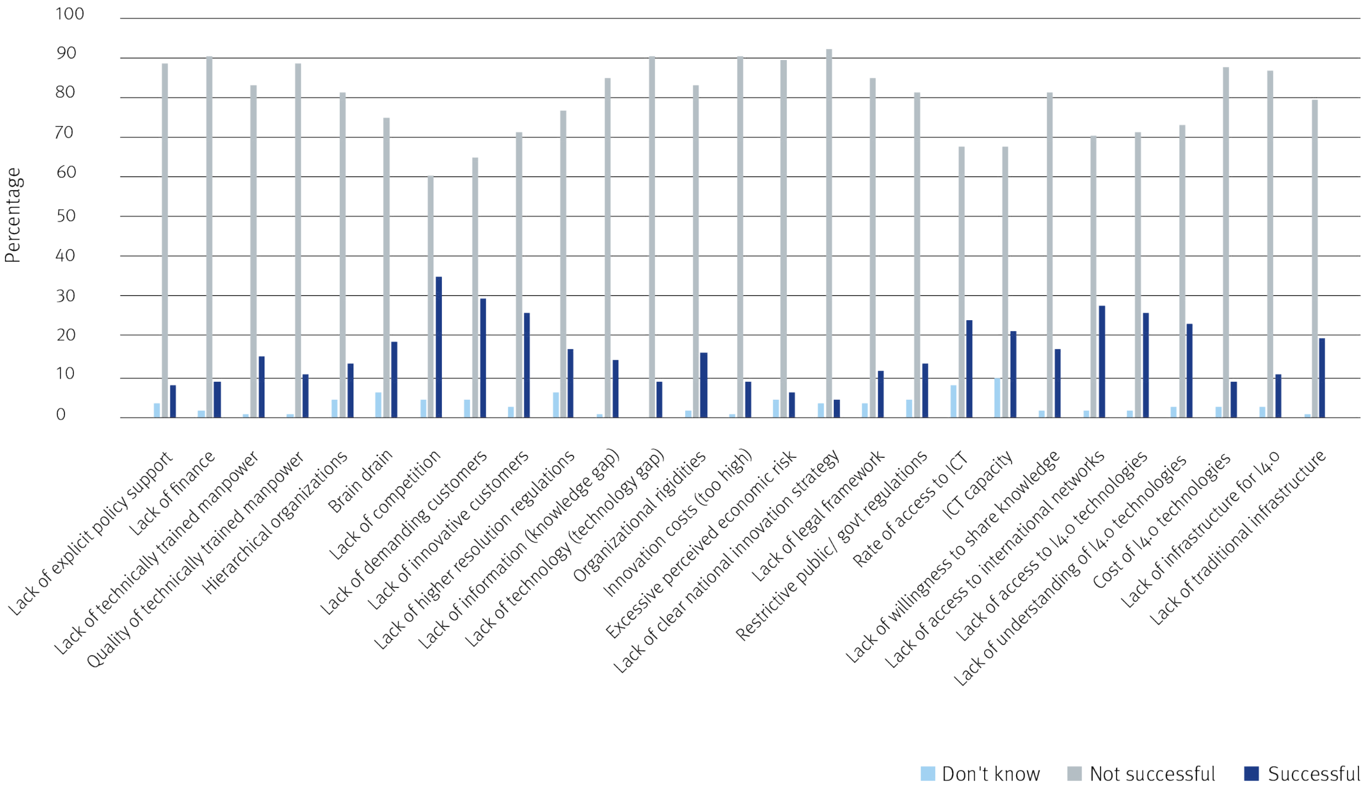
TABLE 5: Additional Employment Needed Per Sector (in millions)

Sub Sector	Additional Employment	Replacement	Total
OEM	1,26	2	3,26
Auto component	2,84	2,97	5,81
Dealership sales	0,43	2,18	2,62
Dealership services	0,29	1,45	1,74
Roadside mechanics	0,16	0,82	0,98
Dealership total	0,89	4,45	5,34

85% of respondents, two groupings[15] emerge; namely: **finance** and **human resources**. These findings align with the groupings that emerge from the responses of industry. However, KBIs do not report **policy** and **technology infrastructure** related issues as barriers to innovation in comparison to industry respondents. The dominant variable under **finance** is 'Innovation costs (too high)' as reported by 91.5% of respondents. Under **human resources**, 'Lack of technically trained manpower' and 'Quality of technically trained manpower' are reported as prominent constraints by 87.2% of respondents.

Automotive manufacturers and component suppliers in India are slowly shifting to smart manufacturing using I4.0 technologies such as sensors, robotics, AR and VR to improve efficiency, enable real-time monitoring and ensure round the clock output. This

Figure 18. Barriers to Innovation – Industry



15 These barriers are arbitrarily grouped based on systems of innovation literature.

shift has high associated costs (Gajdzik et. Al., 2021) and is reflective of the first grouping of **finance**-related barriers in particular, 'innovation costs being too high'.

With respect to **finance**, this is further supported by Figure 14 which shows that only 9% and 6% of KBIs reported relationships with government and industry respectively as 'Recipients of direct funding'. The lack of funds experienced by KBIs may be further explained by the fact that they lack critical collaborations with industry and government in terms of 'Joint research', 'Patents', 'Trademarking' and 'Licensing agreements', all of which are rent generating activities (Boldrin & Levine, 2008). What is clear is that KBIs have a relationship with industry as contract suppliers which is reported by 72% of KBIs (Kaloudis et al., 2019).

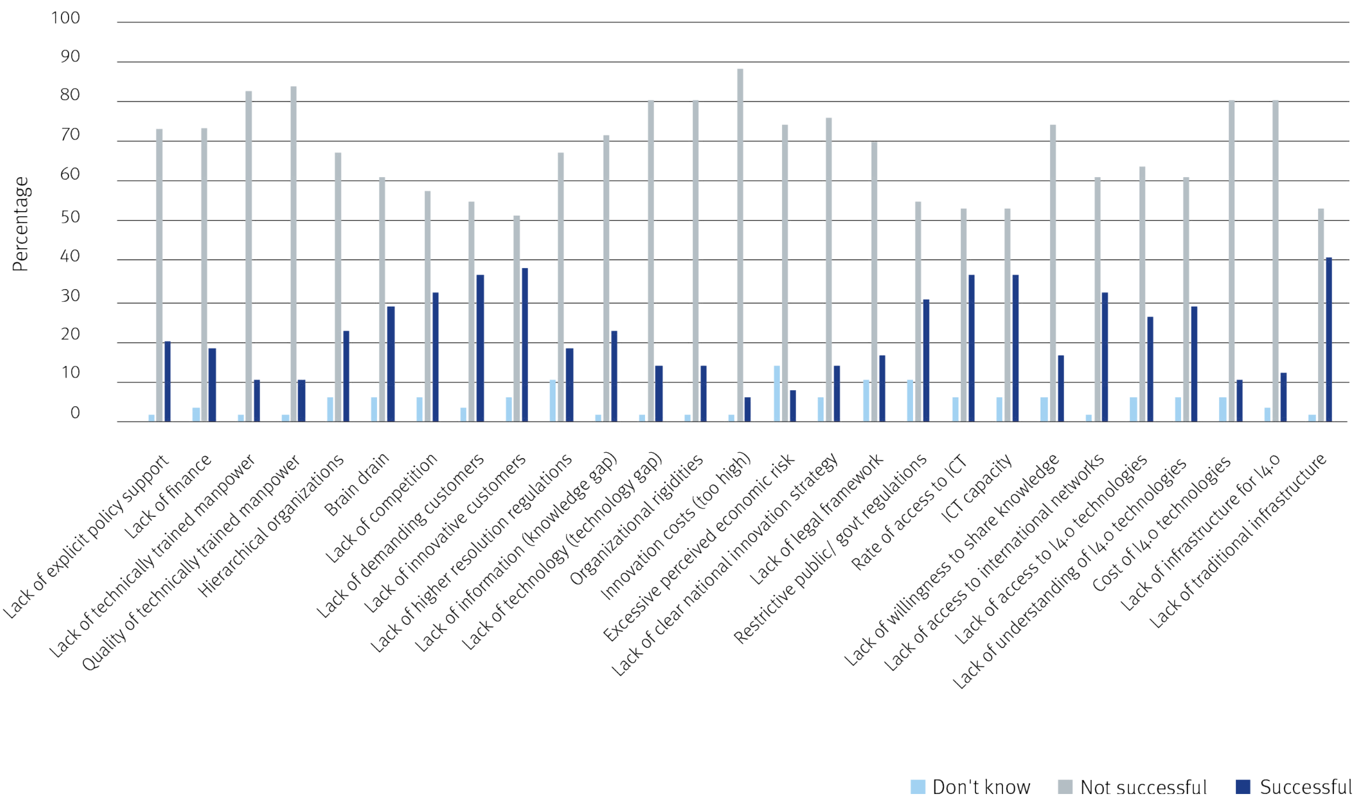
As in the case of industry, KBIs also report **human resources**-related barriers to innovation. The skills gap observed by industry is also relevant for KBIs. Figure 14 shows that none of the KBI respondents have reported linkages with industry in terms of recruitment and secondments. This has an impact on the flow of tacit knowledge between the two actors, which limits KBI's understanding of industry needs in terms of generation of skilled human capital ('Lack of technically trained manpower' and 'Quality of technically trained manpower'). Moreover, KBIs have limited options for 'Recruitment' and 'Secondments' from industry because of existing 'Organizational rigidities' reported by more than 80% of respondents (Alexander et. al, 2020). These 'Organizational rigidities' would affect the flow of knowledge and "prevent inter-organizational knowledge creation" (Alexander et. al, 2020, p.1).

Intermediaries

Intermediaries also report all variables as barriers to innovation (see Figure 20). However, key barriers reported by more than 85% of respondents indicate the emergence of four groupings, namely: policy, human resources, finance and technology infrastructure. These observations align with that of industry respondents.

Firstly, within policy, 'Lack of clear national innovation strategy' is considered a high constraint by 100.0% of respondents. Another variable is the 'Lack of explicit policy support' reported by 90.3% of respondents.

Figure 19. Barriers to Innovation - KBIs



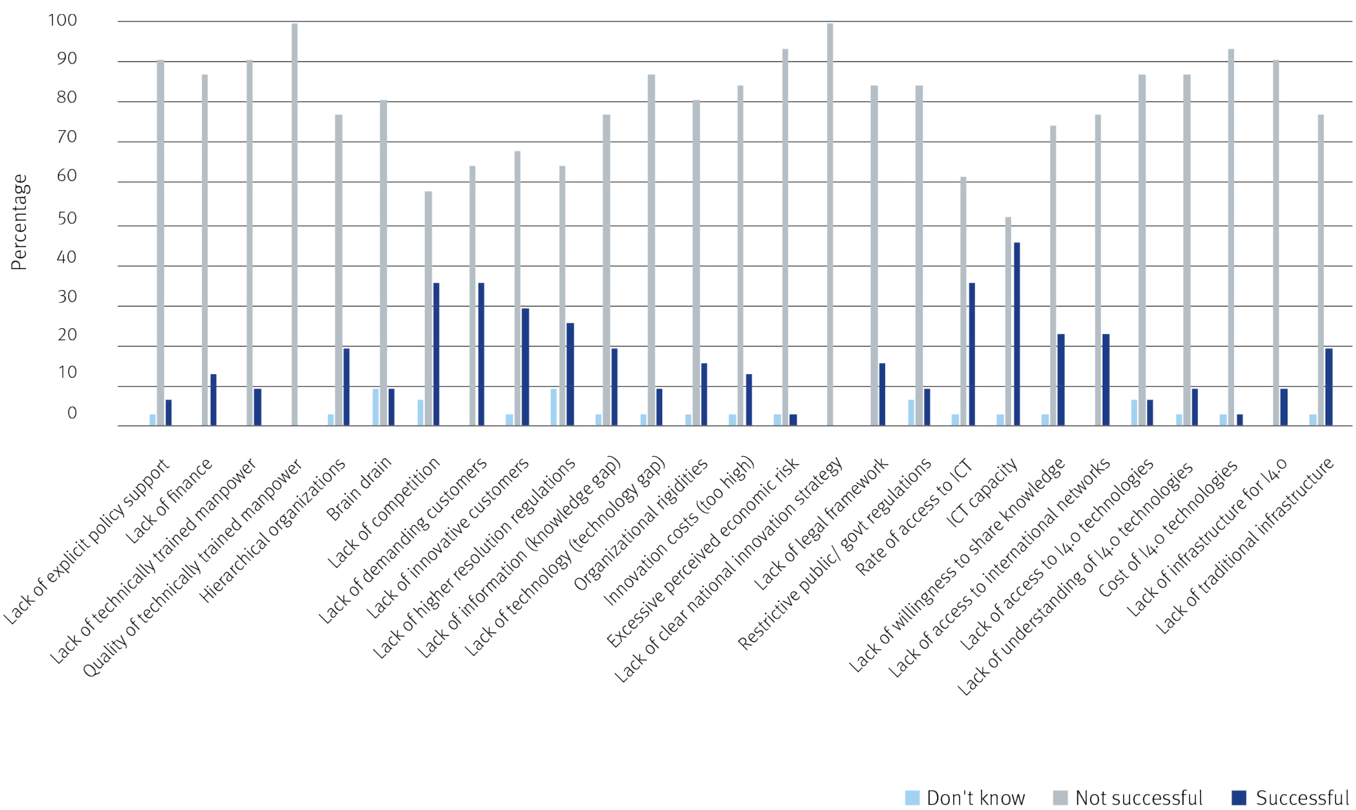
Secondly, under human resources, 'Quality of technically trained manpower' and 'Lack of technically trained manpower' are considered constraints by 100.0% and 90.3% of respondents, respectively. Thirdly, within finance, 'Excessive perceived economic risk' and 'Cost of I4.0 technologies' are indicated as barriers to innovation by 93.5% of respondents. 'Lack of finance' is reported as a barrier by 87.1% of respondents. Finally, under technology infrastructure, 'Lack of infrastructure for I4.0' is considered as a prominent barrier by 90.3% of respondents. 'Lack of technology (technology gap)', 'Lack of access to I4.0 technologies' and 'Lack of understanding of I4.0 technologies' are reported as constraints by 87.1% of respondents.

In the context of policy, intermediary respondents find the lack of sufficient efforts from the side of the government as constraints to innovation. Their responses align with that of industry. As in the case of industry respondents, though the majority of intermediaries (65%) interact with the government through 'Formal meetings', 52% through 'Seminars' and 35% through 'Informal meetings' (see Figure 15), the reported barriers raise similar questions about the content of these communications. Are these communication channels sufficient for the government to understand the needs of the intermediaries involved in the innovation process? How can intermediaries contribute to the policy and strategy making process?

With reference to human resources, the huge skills gap in the automotive sector that is required for I4.0 technology operations has also been indicated as a prominent constraint by intermediary respondents. Very poor intermediary relationships with KBIs and industry in terms of 'Recruitment' and 'Secondments' backs this result.

High R&D costs is a reality for Indian automotive manufacturers. They delve into cost-cutting measures such as rationalising their global manufacturing footprints, exiting from vehicle categories and acquiring technical expertise rather than developing them in-house. The barriers observed by intermediary respondents within finance are supported by the low reporting of their linkages with the government (23% of intermediary respondents), industry (6%) and KBI (3%) as 'Recipients of funding' or through any rent generating activities like 'Joint Patents', 'Trademarking' or 'Licensing agreements'. 42% of intermediaries trade with industry as 'Contract buyers' and suppliers which is a source of funding for them. It is also interesting to

Figure 20. Barriers to Innovation - Intermediaries



note that 52% of intermediaries report linkages with arbitrageurs as 'Recipients of funding' (see Figure 15). Finally, in the context of technology infrastructure, intermediaries have similar observations as industry. Additionally, 'Lack of access to I4.0 technologies' and 'Lack of understanding of I4.0 technologies' have been reported as barriers.

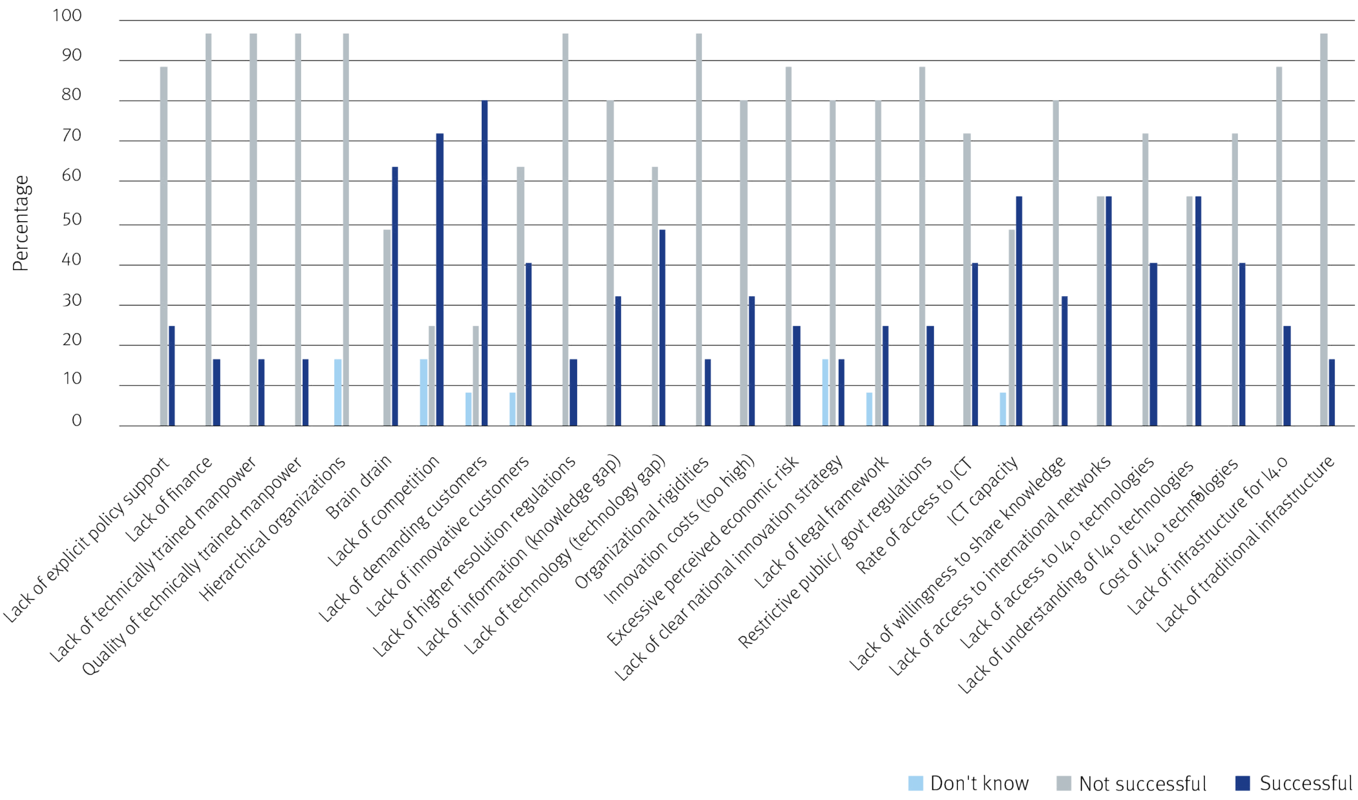
Arbitrageurs

The final interpretation of actor perceptions of barriers to innovation is that of arbitrageurs (venture capital, angel investors and financial institutions) (see Figure 21). The first difference between the responses from other actors is that not all the potential barriers listed are considered a constraint. 'Brain drain', 'Lack of competition' and 'Lack of demanding customers' are not considered constraints by more than 50% of respondents. This may signal the relative isolation of arbitrageurs with respect to other actors in the IASSI, and their inability to extract and process requisite knowledge and information, for example, the impact of the 4IR on the sector (Forbes, 2021).

Finance, human resources, management and technology infrastructure emerge as key groupings with variables reported as barriers by more than 85% of respondents. Within finance, 'Lack of finance' is the prominent variable with 85.7% of respondents indicating it as a barrier. Under human resources, 85.7% of respondents indicate 'Quality of technically trained manpower' and 'Lack of technically trained manpower' as constraints to innovation in the automotive sector. Within management, 'Hierarchical organizations', 'Lack of higher resolution regulations' and 'Organizational rigidities' are reported as crucial barriers by 85.7% of respondents. Under technology infrastructure, 'Lack of traditional infrastructure' is a major constraint reported by 85.7% of respondents.

It is important to note that arbitrageurs are of crucial importance to the innovation ecosystem as they act as sources of finance and knowledge, as well as providing networking opportunities. The presence of well-connected arbitrageurs can help firms minimise risks, improve their performance and survival rate as well as accelerate and increase the effectiveness of their innovation processes (Zook, 2003; Hargadon, 1998; Baygan and Freudenberg, 2000). However, if arbitrageurs are not well-integrated in the innovation ecosystem as evident from the above results, it raises the question as to how effective their role is in the IASSI.

Figure 21. Barriers to Innovation - Arbitrageurs



Summarising the above results from the perspective of each actor, barriers to innovation in the automotive sector as reported by all actors are related to finance and human resources. Industry and intermediary respondents additionally report policy and infrastructure-related constraints. Arbitrageur respondents additionally indicate management-related barriers along with technology infrastructure-related constraints.

Latent Factor Barriers to Innovation

The previous sections have provided an indication of the barriers perceived by the respective actors; the results being presented as frequency analysis. However, one limitation of this is that the frequency analysis lacks significance. Consequently, in addition to the actor level description analysis, and in order to concentrate the critical lens of analysis, factor analysis was applied to the entire dataset to ascertain the perceptions of the system as a whole.

It is crucial to understand which barriers to innovation are significant for the automotive sector. To this end, analysis is used to indicate the underlying factors that significantly influence barriers to innovation, which enables 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 SI. 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 6 (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 7). It should be noted that there are only representations provided for all actors as there are more variables than cases, and it also represents the system as a whole. The consequence of this is that the correlation matrix will have linear dependencies and is non-positive definite, i.e. that some of the eigenvalues of the correlation matrix are not positive numbers which leads to an inability to assess the KMO and Bartlett's Test of Sphericity (IBM, 2016). For the individual actors, barriers to innovation are represented as a frequency analysis.

TABLE 6: 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 7: 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 8) eight factors emerge which account for 62.2% of the total variance explained (TVE). However, based on the scree plot and reliability criteria (Cronbach's Alpha), we report three factors namely, **'Lack of Industry 4.0 readiness', 'Undynamic markets and directives' and 'Insufficient policy and regulatory support'**, which collectively represent 38.13% TVE.

Factor 1- '**Lack of Industry 4.0 readiness**' is the most significant factor barrier to innovation and accounts for 23.8% 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', 'Lack of access to I4.0 technologies' and 'Lack of infrastructure for I4.0' are deemed to be excellent and 'Cost of I4.0 technologies' as very good (Tabachnick and Fidell, 2007)[16].

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

Implementation of I4.0 technologies at a broader organizational level is required for a measurable impact of digital transformation. Before the COVID-19 pandemic, many firms were excited about 4IR implementation with 90% of respondents of McKinsey's 'Annual Industry 4.0 Survey' who were convinced of the value of 4IR technologies. However, the pandemic has altered the flow of resources from 4IR adoption. Many firms, especially SMEs, froze their 4IR initiatives. As per the "Industry 4.0 Sentiment Survey" conducted in late 2019, most firms remain stuck in a pilot trap after they begin their

16 Factor Loading 0.32 (poor), 0.45 (fair), 0.55 (good), 0.63 (very good) or 0.71 (excellent).

Box 5: Industry 4.0 Journey at Metalman

Metalman Auto Private Limited is an automotive company that manufactures sheet metal and tubular components. The firm primarily serves the two and three-wheeler segments and has 10 plants across India.

As part of its transition to Industry 4.0, Metalman has deployed more than 300 robots for Tungsten Inert Gas (TIG) and Metal Inert Gas (MIG) welding.

The key benefits of introducing these robots include:

- Reduced efforts of labour force
- Ensured low cost and high-quality manufacturing
- Improved the firm's market competence

The company's digitalisation journey began with the creation of the 'Digital Transformation' roadmap in 2019, with a focus on having one central platform to bring in data from multiple sources

Metalman is currently in the second phase of its digital maturity assessment activities. The company has completed data collection to justify robotic welding and its return on investment and started replicating it across plants. The team is now preparing to curate and interpret the data to make rational decisions. Artificial intelligence (AI) and machine learning (ML) implementation will start once there is sufficient data to train the system. On the cost management side, data such as the consumption of MIG wire, gas and electricity are monitored for the welding robots.

Preventive maintenance is the next step. Sensors are built into machines to measure their downtime. The team is now working on utilising the data to use it for preventive measures and avoiding unplanned equipment downtime.

Phases of Industry 4.0 journey

Metalman's Industry 4.0 journey can be divided into the following four broad phases:

- Data collection and consolidation
- Visualisation of the data gathered using business intelligence tools
- Usage of analytics and eventually AI and ML, and
- Standardisation and sustenance of the programme

Challenges in Industry 4.0 adoption

- Change management and the need to convince the workforce to adapt to digital ways of working
- Standardisation of the hardware, software and protocols used for communication, and their sustenance

Other technologies and the future of Industry 4.0

- Visual inspection using computer vision and data from sensors that are designed and made for in-house welding wire consumption
- Camera-based inspection is used to identify missing parts and part alignment after welding
- Virtual reality is used as part of marketing, to provide a virtual walkthrough of the manufacturing facility

The way Metalman sees its Industry 4.0 journey five years into the future is a highly automated factory, where the robots would be intelligent to self-program and self-correct when required.

4IR journeys: only 44% were conducting site-wide implementation, and only 38% were looking at horizontal integration beyond the four walls of the factory (Agrawal et al., 2020).

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

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 I4.0 technology among many firms (Bai et al. 2020). Robust evaluation mechanisms and decision support tools can help manufacturing firms understand the impact of I4.0 technologies and effectively implement them. A clear understanding of I4.0 technologies, their benefits and impact can help firms develop an organization-wide 4IR strategy and set implementation targets. Educating the workforce on I4.0 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).

Factor 2- 'Undynamic markets and directives' 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 7.3%, and the relationship of the variables 'Lack of innovative customers' and 'Lack of demanding customers' to the factor can be categorised as excellent while that of 'Lack of higher resolution regulations' as good. Market dynamism 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 (Nguyen & Harrison 2019; Jansen, Van Den Bosch and Volberda 2006; Sirmon, Hitt and Ireland RD, 2007). Volatility and unpredictability characterises 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 required to improve and modify their products and services with innovation continuously to meet customers' needs. 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).

In light of the above, 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 3 – 'Insufficient policy and regulatory support' which are a key foundation to an effective system of innovation (Reiljan and Paltser, 2015), accounts for 7.0% of the TVE with 'Lack of clear national innovation strategy', 'Lack of legal framework', 'Restrictive public/ Govt regulations' and 'Lack of explicit policy support' loading on it. The association between the variables and the factor are 'Excellent' for the first one, 'Very good' for the second one and 'Good' for the last two.

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

Factors 2 and 3 are significant but collectively only account for 14% of the TVE. Factor 1 ranks as the most important factor as it contributes close to 24% of the TVE and should be the main focus of system-oriented policies. Once again this expounds the importance of industry 4.0 technologies as a driver for innovation. 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 individual actor level in order to address the specific needs, and secondly more overarching interventions at the level of the system. Each of these will be articulated in the 'Recommendations' chapter. A structured dialogue between stakeholders is required to orient which policies can be most effectively used to address barriers and challenges. Policies and their targets should not be unattainable or 'out of reach' but issues need to be addressed from a realistic perspective.

Latent factor barriers to innovation - geographical perspective

It is common knowledge that proximity plays an important role in the innovation process as it facilitates the establishment of channels and codes for information flow, making them less costly and more effective (Lundvall 1985). Furthermore, learning-by-interacting creates poles of competitiveness which reflect specific know-how divided between domestic users and producers.

The local character of innovation processes has perceived the region as a locus of innovation (Lalrindiki & Gorman, 2016). This belief is supported by Porter, who states that "competitive advantage is created and sustained through a highly localised process" (Porter 1990: 73). One of the outcomes of the aforementioned approach to innovation was the emergence of territorialised innovation theories (innovative milieu, industrial districts, regional innovation systems) in which local institutional dynamics play a meaningful role (Moulaert/Sekia 2003). Spatial proximity is perceived as a competitive advantage. For these reasons when examining the factor barriers to innovation, spatial considerations are undertaken. All states including and below Maharashtra are considered part of South India and the rest of the states are considered part of North India. Consequently, the Delhi–Gurugram–Faridabad cluster is considered to be in the north of India, and the Mumbai–Pune–Nasik–Aurangabad and the Chennai–Bangalore–Hosur clusters are in the South.

Based on the aforementioned, a factor analysis of barriers in the north of India (see Table 9) shows nine factors that account for 66.65% of TVE. However, as articulated above based on the scree plot and reliability criteria, we report three factors, namely: **'Lack of Industry 4.0 readiness'**, **'Undynamic markets',** and **'Lack of resources and capabilities'** (García-Sánchez et al, 2018)**,** which accounts for 37.2% TVE.

Factor 1 - **'Lack of Industry 4.0 readiness'** once again is the most significant factor barrier to innovation and accounts for 21.7% of the TVE within the sample, hence the population. The association between Factor 1 and the variables namely, 'Lack of understanding of I4.0 technologies', 'Lack of access to I4.0 technologies', 'Cost of I4.0 Technologies' and 'Lack of infrastructure for I4.0' are deemed to be 'excellent', 'excellent', ' very good' and 'good', respectively.[17]

Once again, Factor 2 emerges as - '**Undynamic markets**'. The TVE amounts to 8.3% and the relationship of the variables to the factor are deemed as 'excellent' for 'Lack of demanding customers' and 'Lack of innovative customers' and 'good' for 'Lack of competition'.

Finally, in the case of Factor 3 - **'Lack of resources and capabilities**' the TVE is 7.2%. The variables loading on the factor are 'Organizational rigidities', 'Lack of technology (technology gap)', 'Lack of information (knowledge gap)' and 'Lack of higher resolution regulations'. Their factor loadings are: 'excellent', 'very good', 'very good' and 'good', respectively. In the case of South India (see Table 10), seven factors emerge with a cumulative

17 Factor Loading 0.32 (poor), 0.45 (fair), 0.55 (good), 0.63 (very good) or 0.71 (excellent).

Table 8: System-Wide Barriers to Innovation

Barriers to Innovation Faced by All Actors in the Automotive Sector (N = 357)									
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	Lack of Industry 4.0 readiness	• Lack of understanding of I4.0 technologies • Lack of access to I4.0 technologies • Lack of infrastructure for I4.0 • Cost of I4.0 technologies	0.831 0.810 0.707 0.694	0.8	23.82%	0.807	3354.545	351	0.000
2	Undynamic markets and directives	• Lack of demanding customers • Lack of innovative customers • Lack of higher resolution regulations	0.811 0.792 0.556	0.7	7.29%				
3	Insufficient policy and regulatory support	• Lack of clear national innovation strategy • Lack of legal framework • Restrictive public/ Govt regulations • Lack of explicit policy support	0.736 0.698 0.600 0.575	0.7	7.02%				
4	ICT diffusion	• Rate of access to ICT • ICT capacity	0.865 0.852	0.9	5.76%				
5	Resource constraints	• Lack of technology (technology gap) • Innovation costs (too high) • Lack of information (knowledge gap)	0.686 0.591 0.579	0.7	5.16%				
6	Human capital	• Quality of technically trained manpower • Lack of technically trained manpower	0.889 0.858	0.9	4.86%				
7	Adaptability and financial constraints	• Organizational rigidities • Lack of finance	0.658 0.514	0.2	4.60%				
8	Flexibility and human capital retention	• Brain drain • Hierarchical organizations [TC1]	0.766 0.589	0.5	3.70%				
Cumulative total variance explained					**62.22%**				

Rotation Method: Varimax with Kaiser Normalization.
Determinant = 6.187E-5 = 0.00006187 [1]

1 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. http://users.sussex.ac.uk/~andyf/factor.pdf

Table 9: Barriers Faced by Actors in North India

Barriers to Innovation Faced by All Actors in North India in the Automotive Sector (N = 189)									
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	Lack of Industry 4.0 readiness	• Lack of understanding of I4.0 technologies • Lack of access to I4.0 technologies • Cost of I4.0 technologies • Lack of infrastructure for I4.0	0.812 0.801 0.680 0.572	0.8	21.7%	0.737	1753.764	351	0.000
2	Undynamic markets	• Lack of demanding customers • Lack of innovative customers • Lack of competition	0.842 0.795 0.578	0.7	8.3%				
3	Lack of resources and capabilities	• Organizational rigidities • Lack of technology (technology gap) • Lack of information (knowledge gap) • Lack of higher resolution regulations	0.740 0.669 0.657 0.586	0.7	7.2%				
4	ICT diffusion	• ICT capacity • Rate of access to ICT	0.884 0.852	0.9	6.2%				
5	Policy and regulations	• Lack of legal framework • Restrictive public/ Govt regulations • Lack of clear national innovation strategy	0.772 0.698 0.617	0.6	5.5%				
6	Costs and policy	• Innovation costs (too high) • Lack of explicit policy support • Excessive perceived economic risk	0.797 0.544 0.520	0.5	5.0%				
7	Human capital	• Lack of technically trained manpower • Quality of technically trained manpower	0.881 0.858	0.8	4.5%				
8	Inflexibility and retention	• Hierarchical organizations • Brain drain	0.782 0.594	0.5	4.3%				
9	Resource constraints	• Lack of traditional infrastructure • Lack of finance	0.629 0.517	0.3	4.0%				
Cumulative total variance explained					**66.65%**				

Rotation Method: Varimax with Kaiser Normalization.
Determinant = 5.310E-5

Table 10: Barriers by Actors in South India

Barriers to Innovation Faced by All Actors in South India in the Automotive Sector (N = 168)									
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	Lack of Industry 4.0 readiness	• Lack of understanding of I4.0 technologies • Lack of access to I4.0 technologies • Lack of infrastructure for I4.0 • Cost of I4.0 technologies	0.836 0.810 0.784 0.714	0.8	26.8%	0.789	1798.842	300	0.000
2	Inflexibility and poor human capital retention	• Hierarchical organizations • Brain drain • Lack of competition • Organizational rigidities	0.772 0.645 0.568 0.504	0.7	8.6%				
3	Poor human capital	• Quality of technically trained manpower • Lack of technically trained manpower • Lack of willingness to share knowledge	0.867 0.842 0.509	0.8	7.6%				
4	Undynamic markets	• Lack of innovative customers • Lack of demanding customers	0.840 0.819	0.8	6.43%				
5	ICT diffusion	• ICT capacity • Rate of access to ICT	0.836 0.808	0.9	5.90%				
6	Policy and regulations	• Lack of explicit policy support • Restrictive public/ Govt regulations • Lack of legal framework	0.702 0.685 0.654	0.7	5.12%				
7	Resource constraints	• Innovation costs (too high) • Lack of technology (technology gap) • Lack of information (knowledge gap)	0.651 0.559 0.509	0.7	4.12%				
Cumulative total variance explained					**64.60%**				

Rotation Method: Varimax with Kaiser Normalization. Determinant = 1.123E-5

TVE of 64.6%. On the basis of scree plot and reliability criteria, four factors were reported, namely: **'Lack of Industry 4.0 readiness', 'Inflexibility and poor human capital retention', 'Poor human capital'** and **'Undynamic markets'** with a TVE of 49.5%. Factor 1 - **'Lack of Industry 4.0 readiness'** is the most significant factor barrier to innovation as in the case of North India and all actors. It accounts for 26.8% of TVE. 'Lack of understanding of I4.0 technologies', 'Lack of access to I4.0 technologies', 'Lack of infrastructure for I4.0' and 'Cost of I4.0 technologies' are the variables loading on the factor and are all considered to be 'excellent'.[18]

Factor 2 - **'Inflexibility and poor human capital retention'** accounts for 8.6% of the TVE in the sample, hence the population. The relationship between the factor and the variables 'Hierarchical organizations', 'Brain drain', 'Lack of competition' and 'Organizational rigidities' are 'excellent', 'very good', 'good' and 'fair', respectively.

Factor 3 - **'Poor human capital'** represents 7.6% of the TVE. The variables loading on the factor are 'Quality of technically trained manpower', 'Lack of technically trained manpower' and 'Lack of willingness to share knowledge'. In the case of 'Quality of technically trained manpower', 'Lack of technically trained manpower' their relationship with the factor is 'excellent', and 'fair' in the case of 'Lack of willingness to share knowledge'.

Factor 4 - **'Undynamic markets'** constitutes 6.4% TVE with both the variables 'Lack of innovative customers' and 'Lack of demanding customers' loading as excellent.

The factor barriers reported by system actors in the north and south vary based on the capacities, resources, orientation and demand in the two regions. For instance, while **Lack of Industry 4.0 readiness** is a common barrier in both regions, **market-related barriers** are more prominent in the north compared to **human capital related barriers** in the south. The reporting of different barriers by actors from the north and south suggests the need for innovation policies and strategies for the IASSI to be oriented towards regional requirements. It is crucial that a 'one cap fits all' approach is avoided.

Success of Policy Instruments

Having understood 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 begin with, it is important to understand what public policy instruments are, they can be defined as "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., p..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 frameworks;[19]ii) Economic and financial instruments[20]; and iii) Soft instruments[21]. Phrased differently, these can be considered as "sticks", "carrots" and "sermons". In this vein, the respective perceived success or failure of national policies is reviewed grouping them as per the aforementioned classifications.

An alternative way to classify innovation policy is in terms of supply-side measures and demand-side

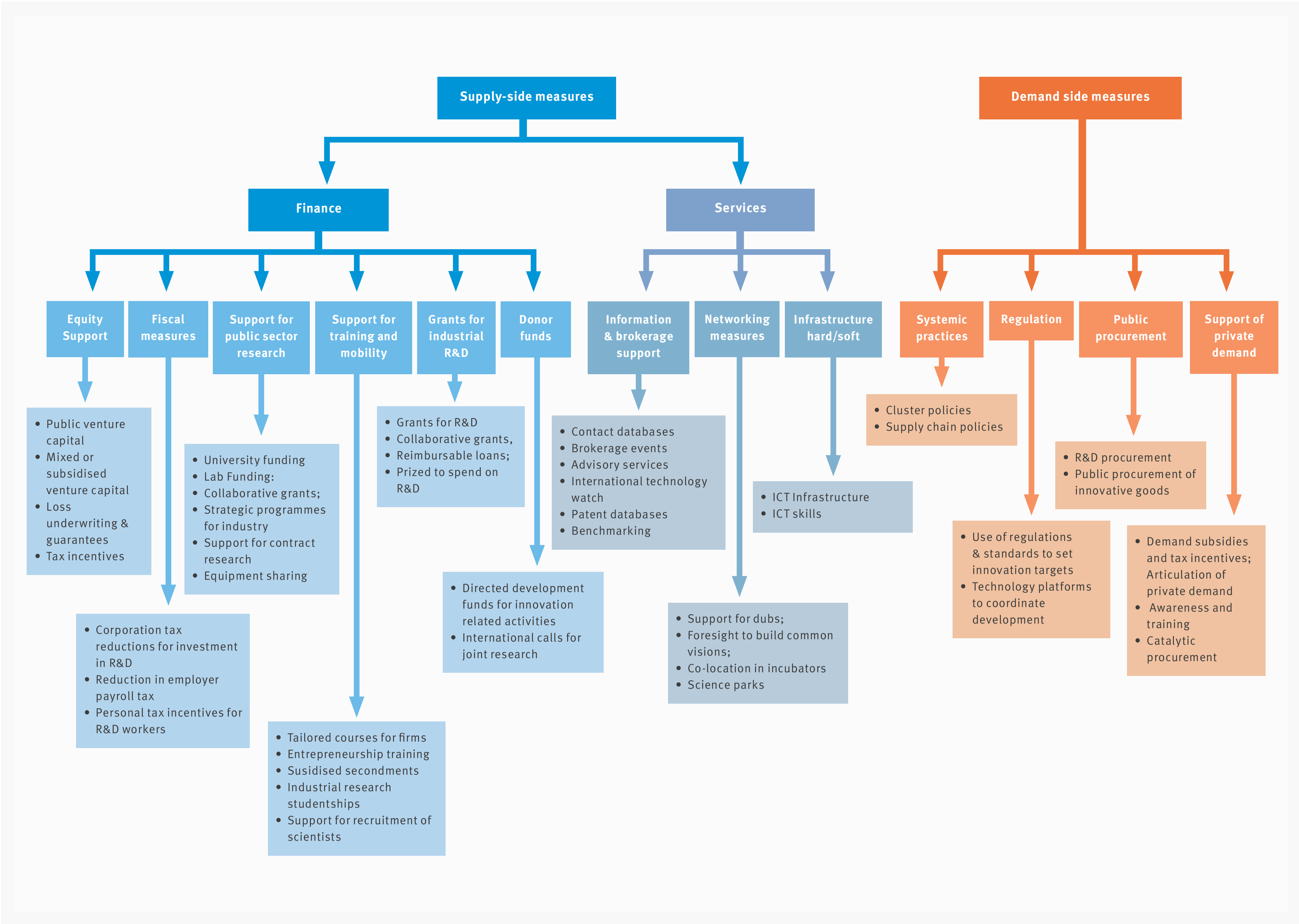
18 Factor Loading 0.32 (poor), 0.45 (fair), 0.55 (good), 0.63 (very good) or 0.71 (excellent).

19 "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 for 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., p.1516

20 "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., p.1516.

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

Figure 22: Policy Taxonomy



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 requirement for products and services or better articulating demand" (Edler and Georghiou, 2007., p. 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 automotive 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. Within this context, unsuccessful and successful policy instruments are generally reported[22] at the cut off levels of 40% and 60% of respondents, respectively.

Industry

From the perspective of industry respondents (see Figure 23), in general, all policy instruments are deemed to be successful, except for the demand side measure of 'Labour mobility laws and incentives' and supply side financial instruments such as 'Govt-backed venture capital' and 'Govt procurement'. This is reflective of the barriers reported by industry related to **policy and finance** (see Figure 19) and can also be explained by industry's poor linkages with government as 'Recipients of funding' (see Figure 13).

A majority of industry respondents (50%) have indicated 'Labour mobility laws and incentives' as an unsuccessful policy instrument. In India, the COVID-19 pandemic generated a major crisis of labour mobility with migrant laborers in many major cities being affected (Rajan et al, 2020). According to a parliamentary panel report submitted to the Rajya Sabha Chairman, the Indian automotive industry suffered Rs 2,300 crore loss per day and job losses of 3.45 lakhs (PTI, 2020). Many OEMs stopped/slowed down their production due to lock down and labour disruption (Rao, 2021).

New, innovative and effective policies as well as flexible and responsible solutions are required for better labour mobility. Long-term socio-economic factors such as demographic imbalances and the 4IR are resulting in the increasing integration of labour markets within and across national boundaries (IOM, 2021). Cross-state and cross-national supply and trade chains, though temporarily disrupted by the COVID-19 pandemic, need to be guided by labour mobility policies that are adaptable.

With respect to 'Govt-backed venture capital', government policies understand that there is a need for "avenues for entrepreneurship development through incubators and accelerators to support the 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[23].

According to Venture Intelligence data, in the first six months of 2021, private equity-venture capital investments in India grew by 33% (Shaik, 2021). As per ETAuto's research, automotive startups attracted a whopping USD 354 billion investments globally in 2019. Automotive startup investments in India stood at USD 1.7 billion. According to KPMG's Venture Pulse study, VC investment in India fell sharply in the first quarter of 2020, due to the economic and political uncertainties generated by the COVID-19 pandemic (Priya, 2020).

Though there are government-driven funding mechanisms such as the "National Research Foundation"

22 Outliers and exceptions are reported despite the cut-off.

23 Government-backed venture capital funds include: SBI Capital Markets Ltd. (SBICAP), Canbank Venture Capital Fund Ltd. (CVCFL), IFCI Venture Capital Funds Ltd. (IFCI Venture), and SIDBI Venture Capital Limited (SVCL).
Source: https://www.indianweb2.com/2015/01/13-govt-venture-capital-firms-for_14.html

(NEP 2020) and the "Technology Acquisition Fund" (NAP 2018) that focus on indigenous R&D and technology acquisition through public private partnerships and the Hybrid Annuity Model, it is still recognised that the absence of venture capital investment thwarts innovation in India (NITI Aayog 2021).

Government procurement is the third unsuccessful policy instrument reported by industry respondents. India is lagging in several indicators related to the assessment of the state of procurement practises (OECD, 2019) namely: "strategic leadership, efficiency, the procurement process's openness, and the legislative framework in place, including subordinate legislation, model documents, and general contract conditions" (Nair, 2021: p.1). There is a lack of a comprehensive central legislation solely governing public procurement in India. 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 Government of India implemented the General Financial Rules (GFR) as its core procurement framework in 1947 which was only updated in 2017. Comprehensive administrative rules and directives on financial management and procedures for government procurement are outlined therein. The principle underlying India's public procurement regime is the acquisition of materials and services of specified quality at the most competitive prices, in a transparent and non-arbitrary manner. Nonetheless, the absence of a central procurement regulation enabling procuring authorities with scope to tweak guidelines and contract formats, leads to confusion on the one hand and rigidity on the other. Consequently, different agencies may even prescribe varying qualification criteria, financial terms, selection procedures, etc. for similar public sector work.

In the case of the Indian automotive sector, in line with the "Make in India" initiative, the government has mandated preference to be given to domestically manufactured vehicles with a minimum of 65% local content in the public procurement of automobiles (PTI, 2018).

With respect to the success of policy instruments, the majority of industry respondents don't know if 'donor funds' are successful. This might be because donors (multilateral organizations) generally do not directly fund industry. They work in close partnership with intermediaries and the government to support industry.

In contrast, the most successful policy instruments (reported by more than 60% of respondents) are demand-side policies, namely, 'Regulation' and 'Tax breaks'. They are followed by a supply-side financial measure, namely, 'Subsidised loans' as well as the supply-side services, 'ICT access' and 'Focused skills development initiatives'.

Regulations can both enhance and constrain business activity. Improvements in firm entry regulation are associated with higher productivity (GII 2020). Amirapu and Gechter (2019) find that restrictive labour regulation in India is associated with a 35% increase in firms' unit labour costs. 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". In real terms, the Doing Business Index of the World Bank highlights that India is among the 10 economies improving the most across three or more areas measured by Doing Business in 2018/19 and has seen clear reforms in the areas of starting a business, dealing with construction permits, trading across borders and resolving insolvency.

Industry respondents report 'Tax breaks' as a successful policy instrument. The importance of tax breaks is recognised by NITI Aayog as a means to promote business sector R&D. Furthermore, the government could focus on specific areas under which top R&D-intensive domestic firms are eligible for tax incentives (NITI Aayog 2021). This is echoed in the STIP 2020 which stipulates that in order to incentivise investments in STI, there is a need to boost "fiscal incentives for industries investing in STI through incremental R&D-based tax incentives, tax credit for investing in facilities for commercialization, tax holidays, tax waivers, target-based tax incentive for specific domains, tax deduction, expatriate tax regimes, remodelling of patent box regime, etc" (DST, 2020: p.21).

Similarly, the draft "National Automotive Policy 2018" articulates that weighted tax deduction on R&D expenditure needs to be retained by defining "applicable R&D expenditure heads and mandate audits by statutory auditors to verify R&D expenditure for companies to qualify for exemption". From the above, it is clear that the overall orientation of policy with respect to 'tax breaks' are markers of success in meeting their targets. The success of 'Subsidized loans' for the automotive sector is exemplified at the national level by schemes and policies of different ministries. The Ministry of New and Renewable Energy (MNRE), announced in 2010 a subsidy of INR 950 million for electric vehicles in order to boost their manufacturing rate. Similar initiatives were championed by other ministries such as the Ministry of Heavy Industries (MHI). Phase I of the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) scheme was initially launched for a period of 2 years, from 2015 to 2017 by the Ministry of Heavy Industries. The first phase of the FAME scheme was implemented through four focus areas namely (i) Demand Creation, (ii) Technology Platform, (iii) Pilot Project and (iv) Charging Infrastructure. Market creation through demand incentives was aimed at incentivising all vehicle segments i.e., 2-wheelers, 3-wheelers, passenger 4-wheelers, light commercial vehicles and buses (PIB, 2019). The extension of the scheme, FAME II, increased the benefit offered from Rs 10,000 per kWh to Rs 15,000 per kWh which is a hike of 50% (PTI, 2021). While FAME II is ongoing, there is a long way to go to meet projected subsidy targets (Chaliawala, 2021).

This is further supported at the state level by specific initiatives which include concessional rates of interest on loans and investment subsidies/tax incentives. For example, the Government of Andhra Pradesh has set a capital subsidy of 50% for common infrastructure within the auto clusters and the Automotive Suppliers Manufacturing Centre (ASMC) developers, up to a maximum of USD 3.07 million. In Gujarat, auto component manufacturers can either avail general incentives under the Gujarat Industrial Policy 2015, or under the scheme for mega/ innovative projects (ILO Consulting, 2020).

Moreover, from a forward-looking perspective, the draft NAP 2018 suggests the need to offer fiscal incentives for green mobility by facilitating changes in the banking norms to ease loans and financing for green vehicles.[24]

However, in light of the above successes, the OECD reports that India is one of the countries which provides the least number of subsidies for the automotive sector in comparison to other major markets. Hence, it could be a challenge for India to achieve its goal of manufacturing nearly 7 million electric vehicles by 2030 (ILO Consulting, 2020).

With regards to 'ICT access', the strategies of the National Policy on Information Technology, 2012 highlight the need "to enable long-term partnership with industry for: i. use of ICT in cutting-edge technology; ii. driving development of new ICT technologies through strategic sectors; 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 use of IT in key economic sectors such as Construction, Textiles, Pharmaceuticals, Banking, Finance, Retail, Energy, Automobiles, Healthcare, Education, Agriculture, Engineering Services, and 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. More specifically, with respect to the automotive sector, the draft NAP 2018 makes no reference to ICT or the 4IR.

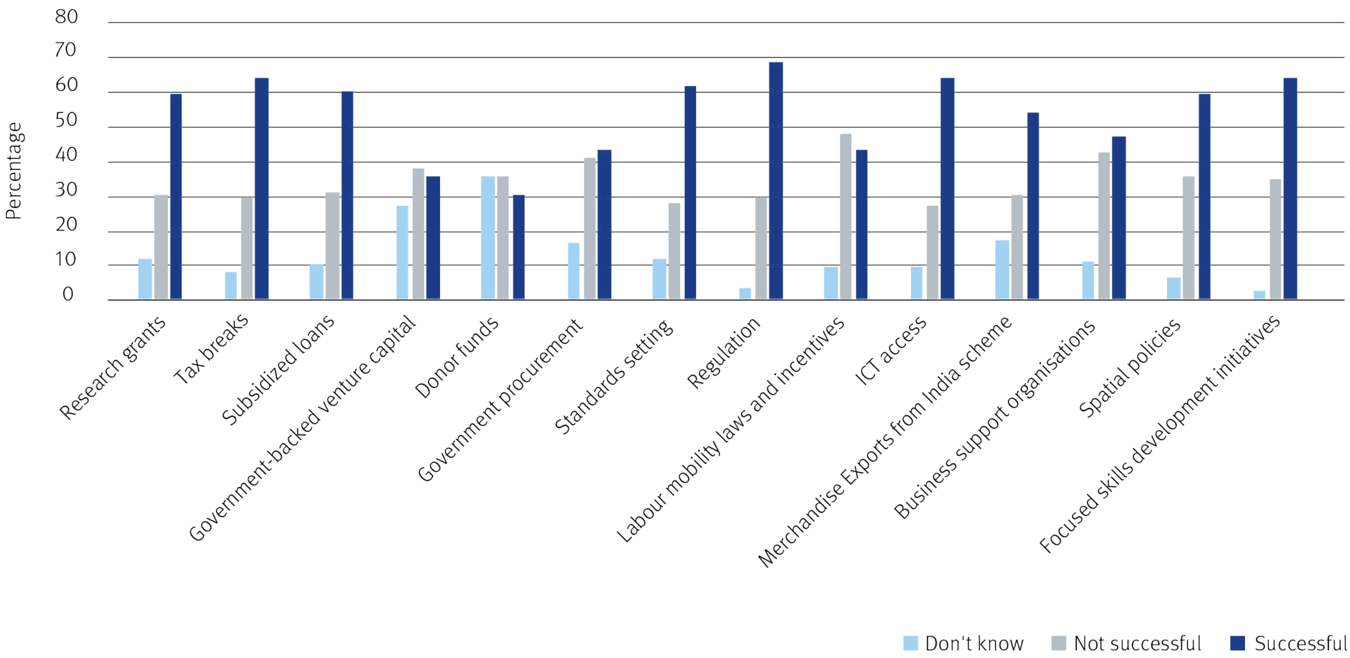
In the context of 'Focused skills development initiatives', major policies such as the draft "National Automotive Policy 2018", the draft "National Education Policy 2020" and the draft "STIP 2020" refer to skills development as a core component of the innovation process. The Global Innovation Index ranking shows from 2015 to 2021, India has improved its ranking with respect to human capital and research from 103 to 54 (Cornell University, INSEAD, and WIPO, 2015; WIPO, 2021).

While 'Regulation' and 'Tax breaks' are reported as successful policy instruments by Industry, **policy-**related issues such as 'Lack of a clear national innovation strategy' and 'Lack of explicit policy support' (see Figure 17) are reported as prominent barriers to innovation.

It is important to note that the first key area of intervention within the government's draft "National Automotive Policy 2018" is oriented towards innovation and R&D. However, during the dissemination process, the policy and its implications need to be clearly transmitted to industry and other system stakeholders. A means to achieve this would be through the government working closely with industry associations in terms of outreach. In addition, it would be beneficial for MHI to highlight the linkages between the draft "National Automotive Policy 2018" and the objectives of the draft "Science Technology and Innovation Policy 2020" as a whole in consultation with DST. This would help in articulating the overall benefits of innovation for the automotive sector.

24 STIP 2020 indicates the need to enhance financial support to industry, especially for MSMEs, for pursuing research through innovation support schemes such as matching grants, small business innovation grants (under fast track mode), innovation vouchers (SMEs), direct innovation grants, risk guarantees, with a special focus on high-risk projects, revenue-based financing, seed grants, loans, research subsidies, equity, research and IPR credits, open innovation schemes, etc.

Figure 23. Success of Policy Instruments - Industry



Knowledge-based institution

From the view of knowledge-based institution respondents (see Figure 29), it is evident that in general, the majority of respondents view all policy instruments as 'successful', except for 'Merchandise Exports from India Scheme', 'Business support organizations' and 'Labour mobility laws and incentives'.

The Merchandise Exports from India Scheme (MEIS) was introduced under the Foreign Trade Policy (FTP 2015-2020) to encourage exports from India. The view of KBIs align with that of government sources which indicated that "the liability under MEIS ballooned from Rs 20,000 crore to about Rs 45,000 crore in FY20 reaching an unsustainable level" (Suneja, 2020). The commerce department has blocked the online system for exporters to apply for tax incentives under the scheme from July 23rd 2020. The government's decision to cap benefits under MEIS at just Rs 2 crore per exporter during the September-December period of FY20 was reported to have impacted the pharma and auto industries, as some of the large companies in these sectors have generally been among the biggest beneficiaries, raking in export benefits of hundreds of crores of rupees each. The scheme, which is not compliant with the World Trade Organization (WTO), has been replaced by the PLI schemes for select sectors, and the Remission of Duties and Taxes on Exported Products (RoDTEP). While the liability under the scheme increased, government sources said India's exports remained range bound. In 2014-15, Indian exports were USD 310 billion and in 2019-20 the export figure was USD 313 billion (Suneja, 2020). In contrast, industry and intermediaries report MEIS as successful (57% and 51%, respectively) which may be a result of many firms from the automotive sector reaping a sizable chunk of benefits from the scheme. The second unsuccessful policy instrument reported is 'Business support organizations'.

'Labour mobility laws and incentives' is indicated as an unsuccessful policy instrument by KBIs. This is in line with the assertions of the draft NAP 2018 which reflects the need for better labour mobility laws and incentives in terms of demand and supply of labour. The Automotive Skills Development Council (ASDC) has been set up to implement a Labour Market Information System (LMIS) for aggregated information of certified candidates and serve as a marketplace to match demand and supply of skilled labour as well as to support auto component cluster programmes in dedicated regions.

KBI respondents are divided on whether 'Donor funds' are successful (with 42.6% respondents reporting it as both 'Successful' and 'Not successful'). This raises questions on the level of direct engagement of KBIs in multilateral projects related to the automotive sector. There is a varied response with respect to donor funds among other system actors such as industry, intermediaries and arbitrageurs. In general, multilateral organizations work closely with intermediaries, especially industry associations and chambers of commerce in the framing and implementation of interventions, which reflects the view of the majority of respondents from intermediaries.

In terms of policy success, supply-side service measures such as 'Focused skills development initiatives' (74.5%) and 'ICT access' (72.3%) are deemed to be the most successful, along with the supply-side financial policy measure 'Research grants' (72.3%). However, 'Innovation costs too high', 'Lack of technically trained manpower' and 'Quality of technically trained manpower' are reported as high constraints to innovation by KBIs (see Figure 20).

This raises the question as to the orientation and quality of skills development taking place within KBIs and whether they are aligned to the needs of the industry. This viewpoint is convergent with the draft "National Automotive Policy 2018" which indicates "the rolling out of a comprehensive long-term (10 year) roadmap which will enable the industry and support agencies to define skill development, improve the skill development and training ecosystem, increase the accountability of the Automotive Skills Development Council (ASDC) through performance-based funding linked to metrics such as the incremental employment generated, level of employment, curriculum coverage, industry feedback, etc." (DST, 2018). NAP 2018 also outlines the importance of establishing shared training and testing facilities in these clusters for technology improvement and skill development as part of the "Skill India" programme.

Furthermore, the National Education Policy 2020 indicates the need for a flexible and multidisciplinary approach for education with stronger linkages to industry in order to allow graduates access to industry. As part of holistic education, internships with local industry, businesses, etc. have been encouraged so that students may actively engage with the practical side of their learning and, as a by-product, further improve their employability.

In the case of funds, 77% KBIs reported receiving funds from arbitrageurs and 9% from the government (see Figure 14). The success of research grants as a policy instrument can be attributed to the funds received from the government. It is surprising to note that only 13% of KBIs have reported at least one linkage with intermediaries in terms of 'Joint research'.

Finally, KBI respondents view the demand-side measures: 'Regulation', 'Standard setting' and 'Spatial policies' as successful, although not as much as supply-side financial and supply-side service measures. These results are in line with KBI perspective on barriers such that they do not consider **policy** and **technology infrastructure** related issues as prominent barriers to innovation.

In terms of 'Regulation', the response of KBIs is convergent with that of industry and has been explained in the previous section.

'Standard setting' has been reported by KBIs as a successful policy instrument. It is a driver for innovation and stimulates firms to change their behavioral patterns and enables them to be more technologically adaptive, leading to overall increased productivity and competitiveness. Standards in the automotive sector in India range from the Euro I equivalent India 2000 norms to the currently ongoing Bharat Stage-VI (BS-VI) norms. The Auto Fuel Policy 2025 has laid down the emission and fuel roadmap up to 2025 which envisaged the implementation of BS-IV emission norms in India by 2017, BS-V norms in 2020/2021 and BS-VI from 2024. However, due to increased pollution levels in the NCR, the government leapfrogged to BS-VI emission norms in 2020. The government has also set the requirement of corporate average fuel consumption standards for passenger vehicles.

Moreover, the draft NAP 2018 outlines the rollout of a comprehensive long-term (10 year) roadmap that will define the emission standards applicable after BS-VI with a target of harmonising with the most stringent global standards by 2028, across all vehicle segments.[25]

In India, vehicle technology has evolved to meet the safety regulations notified as per the Safety Roadmap adopted by the Central Motor Vehicle Rules - Technical Standing Committee (CMVR-TSC). Today the vehicle technology in India is at par with the international benchmarks as Indian safety standards are being aligned with Global Technical Regulations (GTR) and

25 Define a roadmap for harmonising key standards and testing methods with global benchmarks. Agencies like ARAI and NATRiP should be upgraded in line with the harmonisation plan, to develop capabilities which are at par with global testing and certification agencies. Also evaluate accession to the UNECE WP.29 1958 agreement within the next 5 years, which will eliminate a major technical barrier to trade. Harmonise AIS and BIS standards on safety critical parts over next 3 years, with eventual target of single standards.

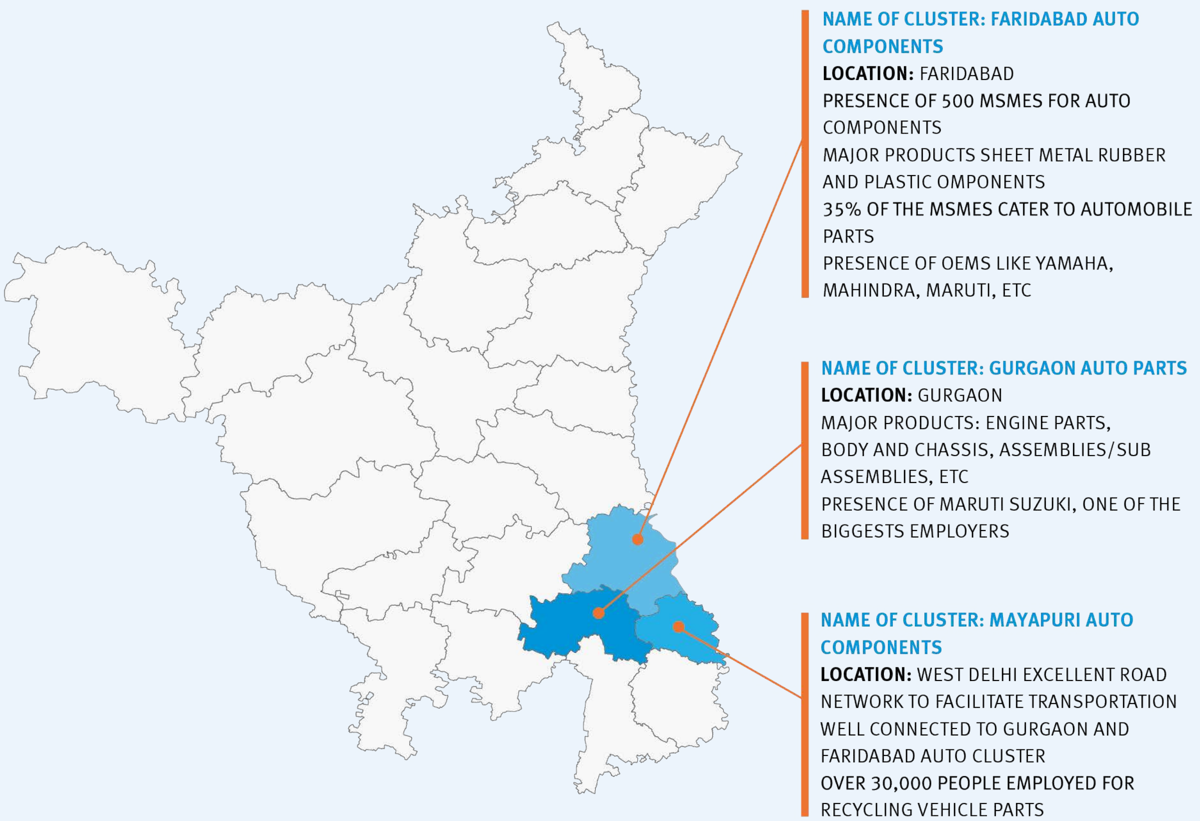
UN Regulations. The government is currently working towards the implementation of Bharat New Vehicle Safety Assessment Program (BNVSAP).

Several ministries such as the Ministry of New and Renewable Energy (MNRE) and the Ministry of Heavy Industries (MHI) have championed response to these standards. This has led to increased collaborations and focused R&D programmes within the knowledge space in areas such as new and renewable energy technologies including hydrogen and fuel cells. For instance, ARAI is working on the development of Hydrogen PEM Fuel Cell with the industry. There is also the emergence of new technological solutions such as the Digital Twin Spark ignition (DTSi) and the increased use of electronic control units to monitor and manage the increasing complexity in the engine and the rest of the vehicle (Krishnan, 2016).

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 and aggregation, as well as industrial and technology parks. For example, a cluster approach to manufacturing can assist firms in achieving competitive advantage by promoting their common interests, identifying the most promising opportunities to encourage further innovation, developing worker skills, and addressing issues that affect productivity. Firms will have improved access to suppliers of raw materials, parts and components, machinery, skills and technology as well as other supporting services that can enable them to enhance competitiveness.

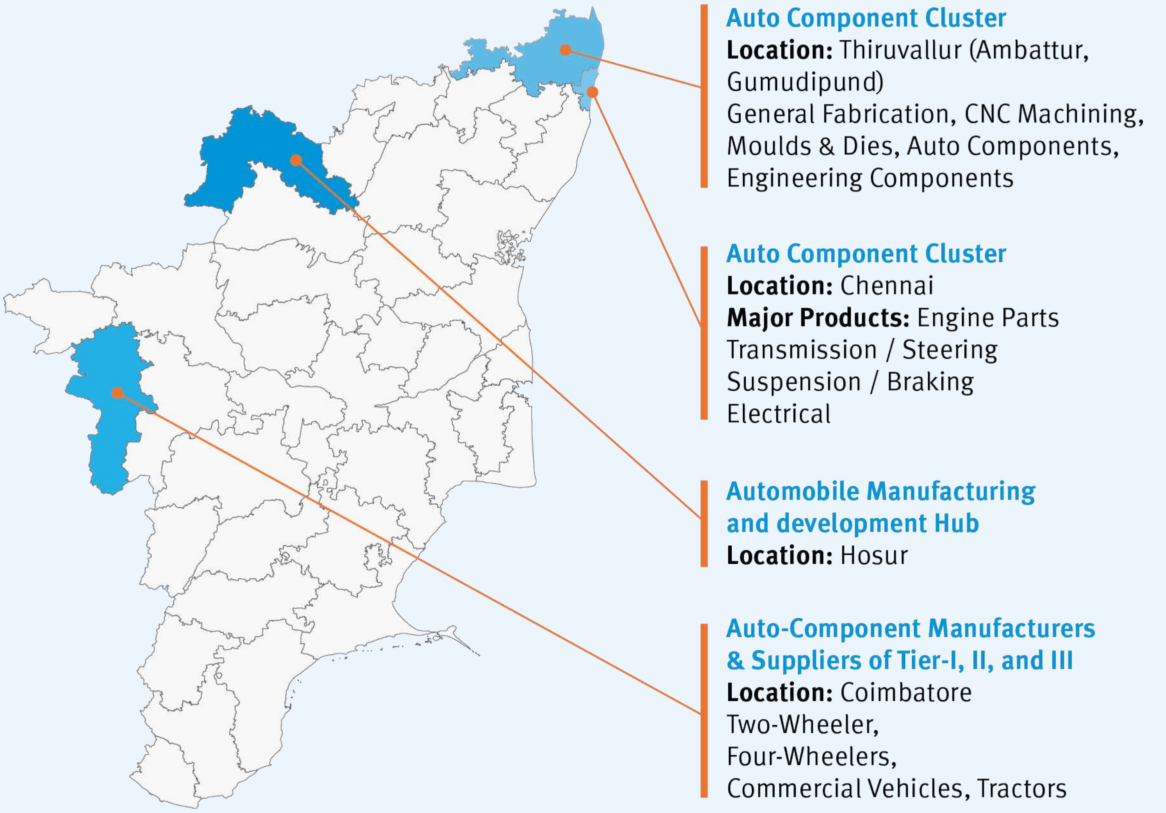
In India, several national and state-level initiatives have been undertaken to achieve the aforementioned benefits. The "National Manufacturing Policy 2011" highlighted the importance of

Figure 24. Northern Automobile Cluster



Source: IBEF

Figure 25. Tamil Nadu Cluster



clustering and aggregation through National Investment and Manufacturing Zones (NIMZs)[26]. According to the policy, "NIMZs were planned to be developed as integrated industrial townships with state-of-the art infrastructure and land use on the basis of zoning; clean and energy efficient technology; necessary social infrastructure; skill development facilities, etc., to provide a productive environment to persons transitioning from the primary sector to the secondary and tertiary sectors" (DPIIT, 2011).

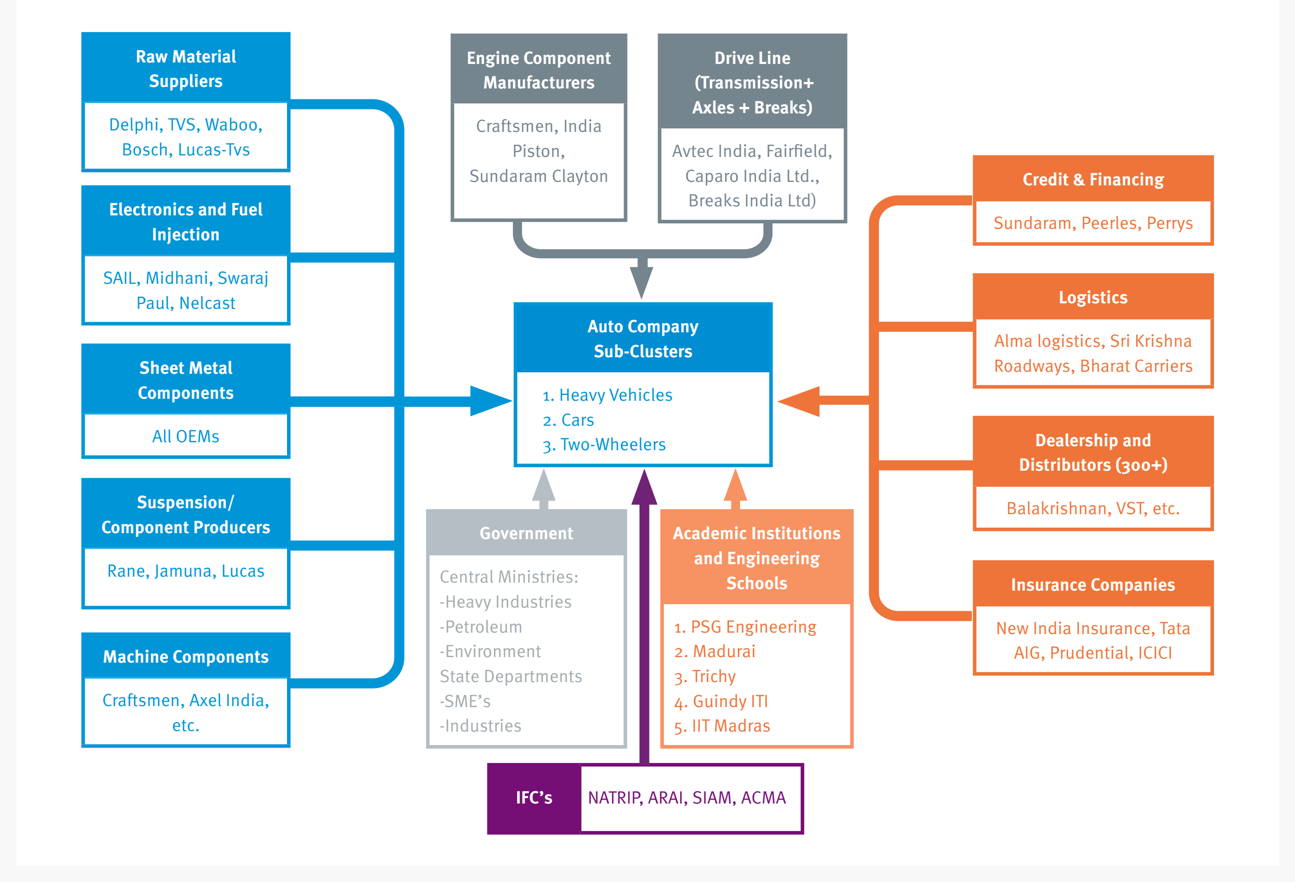
Unlike special economic zones which are aimed at advancement of exports as outlined in the Special Economic Zones Act, 2005, NIMZs27 focus on industrial growth in collaboration with state governments. NIMZs have a sectorial focus and foster interdependencies. The central government provides external physical infrastructure linkages while the state government supports through a Special Purpose Vehicle (SPV) to implement the policy.

Within India, there are three major automotive clusters, namely, the northern cluster, southern cluster and western cluster. The Northern Automobile Cluster (see Figure 24) is located in the National Capital Region (NCR) covering Delhi, Gurugram and Faridabad (Haryana). The well-connected road network of Delhi and Haryana with the rest of the country and the 165 km long

26 Department for Promotion of Industry and Internal Trade (DPIIT) is the nodal agency for NIMZs.

27 The government has announced eight Investment Regions along the Delhi Mumbai Industrial Corridor (DMIC) project as National Investment and Manufacturing Zones (NIMZs): (i) Ahmedabad-Dholera Investment Region, Gujarat, (ii) Shendra-Bidkin Industrial Part city near Aurangabad, Maharashtra, (iii) Manesar-Bawal Investment Region, Haryana, (iv) Khushkhera-Bhiwadi-Neemrana Investment Region, Rajasthan, (v) Pithampur-Dhar-Mhow Investment Region, Madhya Pradesh, (vi) Dadri-Noida-Ghaziabad investment Region, Uttar Pradesh, (vii) Dighi Port Industrial Area, Maharashtra, and (viii) Jodhpur-Pali-Marwar Region in Rajasthan.
Fourteen NIMZs outside the DMIC region have also been given in-principle approval (i) Nagpur in Maharashtra, (ii) Prakasam in Andhra Pradesh, (iii) Chittoor in Andhra Pradesh, (iv) Medak in Telangana, (v) Hyderabad Pharma NIM in Rangareddy and Mahbubnagar Districts of Telangana, (vi) Tumkur in Karnataka, (vii) Kolar in Karnataka, (viii) Bidar in Karnataka, (ix) Gulbarga in Karnataka, (x) Kalinganagar, Jajpur District in Odisha, (xi) Ramanathapuram District of Tamil Nadu, (xii) Ponneri, Thiruvallur District, Tamil Nadu, (xiii) Auraiya District in Uttar Pradesh, and (xiv) Jhansi District in Uttar Pradesh. National Investment and Manufacturing Zones (NIMZs) (pib.gov.in)

Figure 26. System Actors in the Cluster



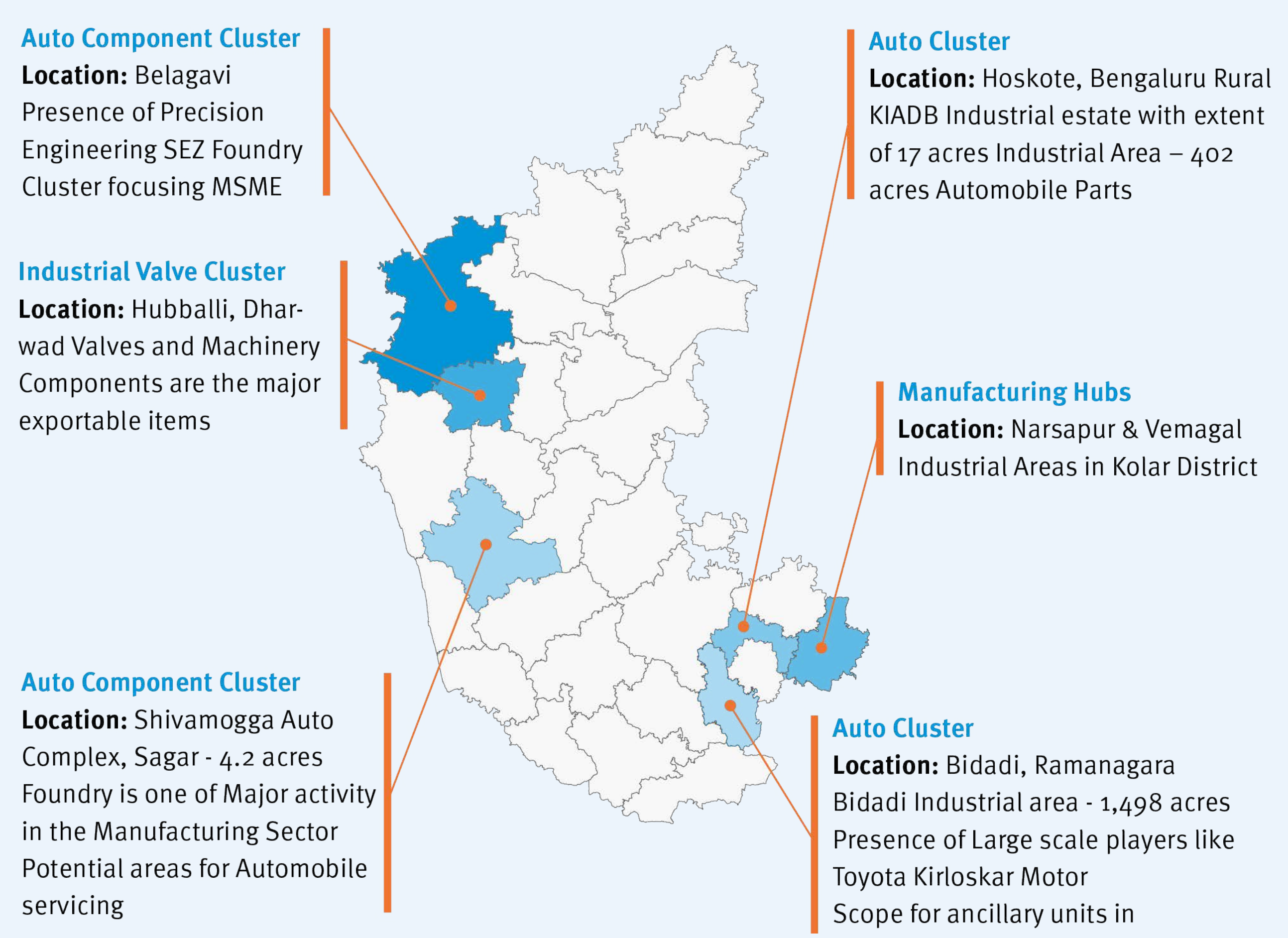
Yamuna expressway helped to form this cluster. Within the northern cluster, Haryana has a strong presence of automobile manufacturers such as Maruti-Suzuki, Hero-Honda, Honda Motors and Escorts which have led to the development of a large number of ancillaries. The Gurugram-Manesar-Bawal region has been identified as an auto hub by the Government of India. A number of auto and auto component units have already set up base in this hub. The NCR cluster hosts R&D and testing facilities and is well-connected with the rest of India. For example, the International Centre for Automotive Technology (ICAT) located in Manesar provides testing and R&D services to the industry and was set up as a part of the National Automotive Testing & Research & Development (R&D) Infrastructure Project (NATRiP).

Chennai, Hosur and Bangalore form the major locations in the southern automotive cluster (see Figure 25). The Chennai-Bangalore industrial corridor is in this region. The state governments have been providing the required facilities and also the incentives in order to further promote the sector. One of the objectives of the Tamil Nadu Industrial policy 2014 was to strengthen the state as a manufacturing hub and attract incremental investments of over 10% every year in the sector. Tamil Nadu has an advanced infrastructure with a superior road and rail network, 3 major ports, 23 minor ports, and 7 airports across the state which provides exceptional connectivity (Frost and Sullivan, 2018). The presence of IT and technology parks, a skilled workforce, as well as a wide range of suppliers, institutes of collaboration and linked services (see Figure 26), have made the cluster highly competitive. It is considered among the top 10 global auto clusters (Okada & Siddharthan, 2008). Hosur (Tamil Nadu) is located close to Bengaluru, a major IT hub which provides a plethora of investment opportunities in the region.

Karnataka hosts five auto clusters (see Figure 27) in Dharwad, Belgaum, Shivamogga, Ramanagara and Bengaluru Rural with excellent support infrastructure. The state has leading R&D institutions that provide knowledge services and sectoral training institutes that cater to the skills requirement of the cluster (Government of Karnataka, 2014).

The western automotive cluster (see Figure 28) consists of Mumbai-Pune-Nashik-Aurangabad and Sanand-Dholera-Halol in Maharashtra and Gujarat, respectively.

Figure 27. Karnataka Automotive Cluster



Source: IBEF

Automobile clustering in Mumbai-Pune region started early in India due to its proximity to the coast for the import of heavy machinery via Mumbai port, availability of power supply, skilled labour pool and good infrastructure. Gujarat's strong cluster level approach has contributed to its emergence as a key investment destination for major automotive OEMs and ancillary companies, supported by modern infrastructure, premium social infrastructure, civic amenities, and centres of excellence.

Building on the above success of spatial policies for the promotion of innovation, there is a clear requirement for an up-to-date repository of cluster information in India located within a national observatory where this information is accessible to all system actors.

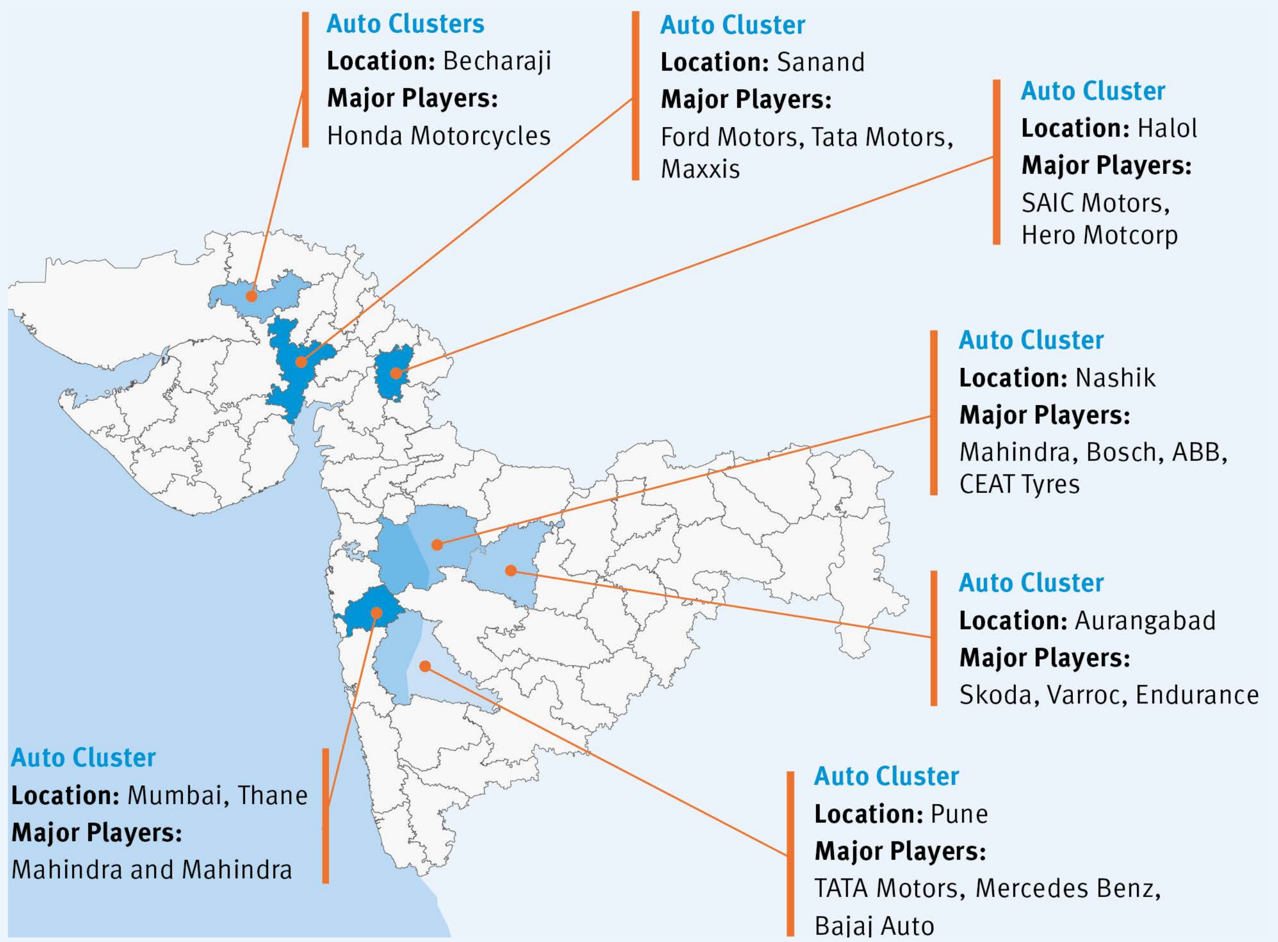
Coherent spatial policies are crucial to build a robust innovation ecosystem that encourages private enterprises in building in-house research capacity along with "collaborating with knowledge institutions to pursue market-relevant research through mutually decided agreements" (DST, 2020, p.20).

Intermediaries

Intermediaries report all policy instruments as successful (see Figure 30), except for 'Subsidised loans' for which their response is divided. This is underscored by their indication of finance-related barriers to innovation such as 'Excessive perceived economic risk', 'Cost of I4.0 technologies' and 'Lack of finance' (see Figure 21).

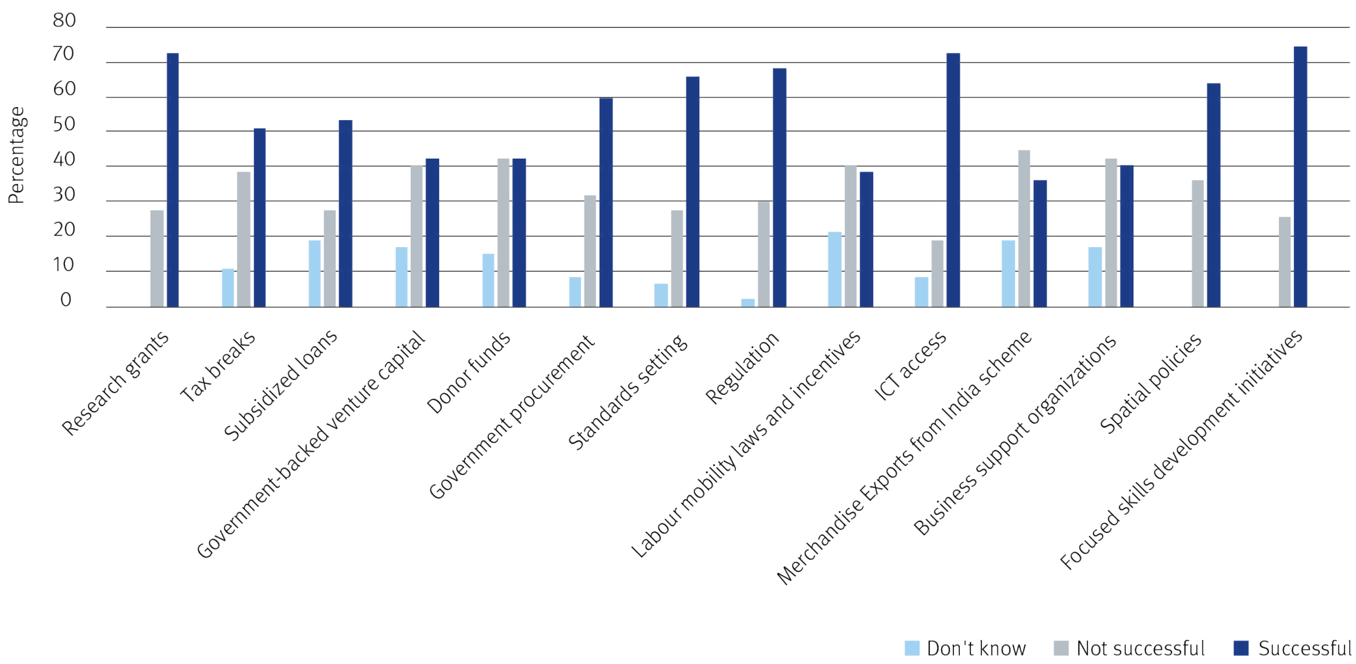
The most successful demand side measures reported are 'Standards setting', 'Regulation' and 'Spatial policies'. This mirrors the view of KBIs and that of industry in the case of 'Regulation'. Supply-side service measures such as 'ICT access' and 'Focused skills development initiatives' are also deemed to be successful. Supply side financial measure, 'Research grants' is also considered a successful instrument by intermediaries. These results are convergent with the views of KBIs; and, with respect to Industry in the case of 'ICT access' and 'Focused skills development initiatives'. The respective explanations are provided in the previous sections.

Figure 28. Western Automotive Cluster



Source: IBEF

Figure 29. Success of Policy Instruments - KBI



Box 6: Material Compatibility and Emission Performance Measurement with Ethanol Blended Gasoline (E20)

Objective:

ARAI conducted a study along with SIAM, ACMA, IOCL and IIP to assess the impact of ethanol blended gasoline (E20) vis-à-vis commercial gasoline on old and new 2-wheelers and 4-wheelers (up to BS IV level).

Approach:

The project involved the following activities:

- Laboratory measurements on materials (metals and non-metals) used in fuel-system components for material compatibility evaluation
- Field trials on 2W and 4W vehicles (old and new) for assessment of periodic mass emissions during mileage accumulation, evaporative emissions (SHED Testing) of 4W, deposit rating of 2W and 4W engine parts, and hot and cold startability

Outcomes:

- Impact of E20 on metals tested was found to be insignificant based on the corrosion rates
- Impact of E20 on tensile strength and volume change properties of PA66 was found to be more than commercial gasoline
- The vital information generated can be utilised by design engineers for selection, modification of materials for various components of fuel-systems of vehicles

ARAI will be undertaking a further study of E20 fuel on E10 compatible BS VI vehicles under a project awarded by MoPNG.

Source: Bawase, & Thipse, 2021

One of the roles of industry associations is to liaise with the government in advocating solutions for the challenges faced by industry. They work closely with the government on policy issues, interfacing with thought leaders, and enhancing efficiency, competitiveness and business opportunities for industry through a range of specialised services and strategic global linkages. It also provides a platform for consensus-building and networking on key issues (CII, 2022).

Similarly, institutions supporting technical change collaborate with the government for setting standards and designing policies and regulations. The role of intermediaries in designing policies and their instruments can also be evidenced by 65% of intermediaries reporting linkages with the government through 'Formal meetings', 52% through 'Seminars' and 35% through 'Informal meetings' (see Figure 15).

In the automotive sector in India, the Automotive Research Association of India (ARAI) is a leading institution supporting technical change and is an autonomous body affiliated to the Ministry of Heavy Industries (MHI). The ISTC has been assisting the government in formulating automotive standards and regulations (ARAI, 2022). ARAI undertakes research and development programmes for developing indigenous technologies and solutions for the mobility sector. These are in addition to the various assignments executed by ARAI for the industry with regards to certification, testing, validation, optimisation and developmental work.

Arbitrageurs

The final actor perspective on the relative success of policy instruments is that of arbitrageurs (Figure 31). Again, most of the policy instruments are reported as successful, except for 'Labour mobility laws and incentives', 'Business support organizations' and 'Focused skills development initiatives'. These observations converge with that of industry and KBIs in terms of 'Labour mobility laws and incentives' and with KBIs with regards to 'Business support organizations'. These results correspond to the majority of arbitrageurs' views that barriers (see Figure 22) related to **human resources** and **management** are prominent.

Figure 30. Success of Policy Instruments - Intermediaries

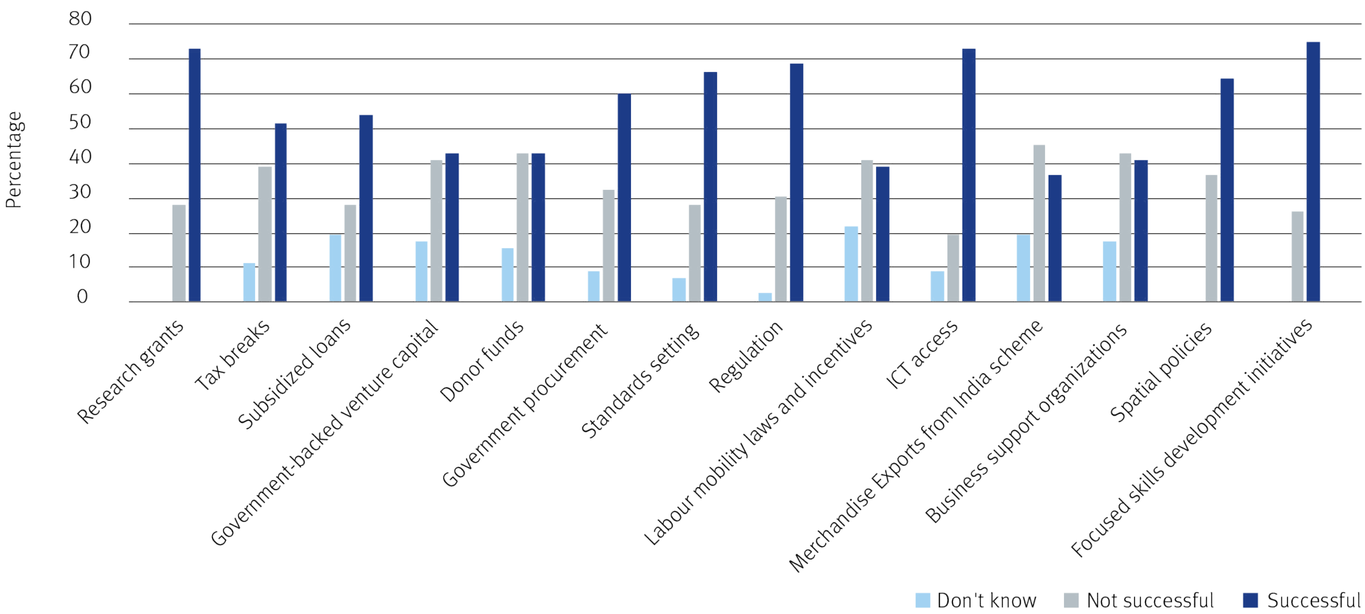
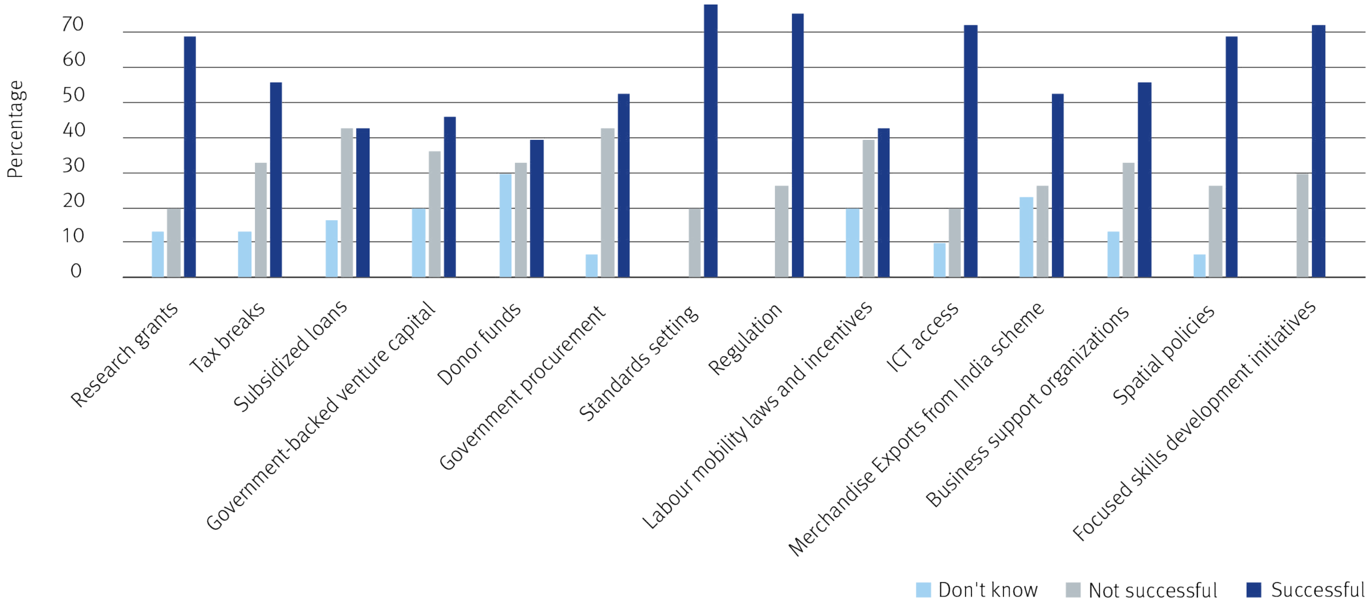


Figure 31. Success of Policy Instruments - - Arbitrageurs



The explanations for 'Labour mobility laws and incentives', 'Business support organizations' and 'Focused skills development initiatives' as unsuccessful policy instruments have been provided in previous sections. With respect to 'Business support organizations', a means to explain the view of arbitrageurs is that only 21% of them have reported linkages with intermediaries through 'Formal meetings' and 'Seminars', and 14% through 'Informal meetings' and 'Joint research' activities.

In the cases of 'Govt-backed venture capital' and 'ICT access', arbitrageurs have a divided response (33.3% for both 'Successful' and 'Not successful'). Respondents also indicate they are unaware if the 'Donor funds', 'Govt procurement' and 'Merchandise Exports from India Scheme' are successful. These results may be explained by the relative isolation of arbitrageurs as an actor within the SSI, which is evidenced by their very few intra- and inter-linkages (see Figure 16). The presence of only a few government-backed venture capital funds in India validate the divided response of arbitrageurs.[28]

28 A noteworthy observation is that the majority of venture capital funds are private sector-led as compared to government-backed. Some government-backed venture capitals in India 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).

In general, the view of arbitrageurs differs from that of other actors who all hold a clear view of the success of these policy instruments.

The government has introduced several policies that support the "operation of alternate investment funds (AIFs) and start-ups in India, with sector-specific initiatives to turbocharge high-priority industries". In addition, several regulatory programmes have been introduced to boost the Indian startup ecosystem. Flagship programmes like "StartupIndia", "Digital India", and the Alternative Investment Policy Advisory Committee (AIPAC) continue to improve the environment for startups and investors. India's ranking on the World Bank's Ease of Doing Business also increased significantly (from 130 in 2016 to 63 in 2021), improving investor confidence in the regulatory ecosystem (Sheth et al., 2020).

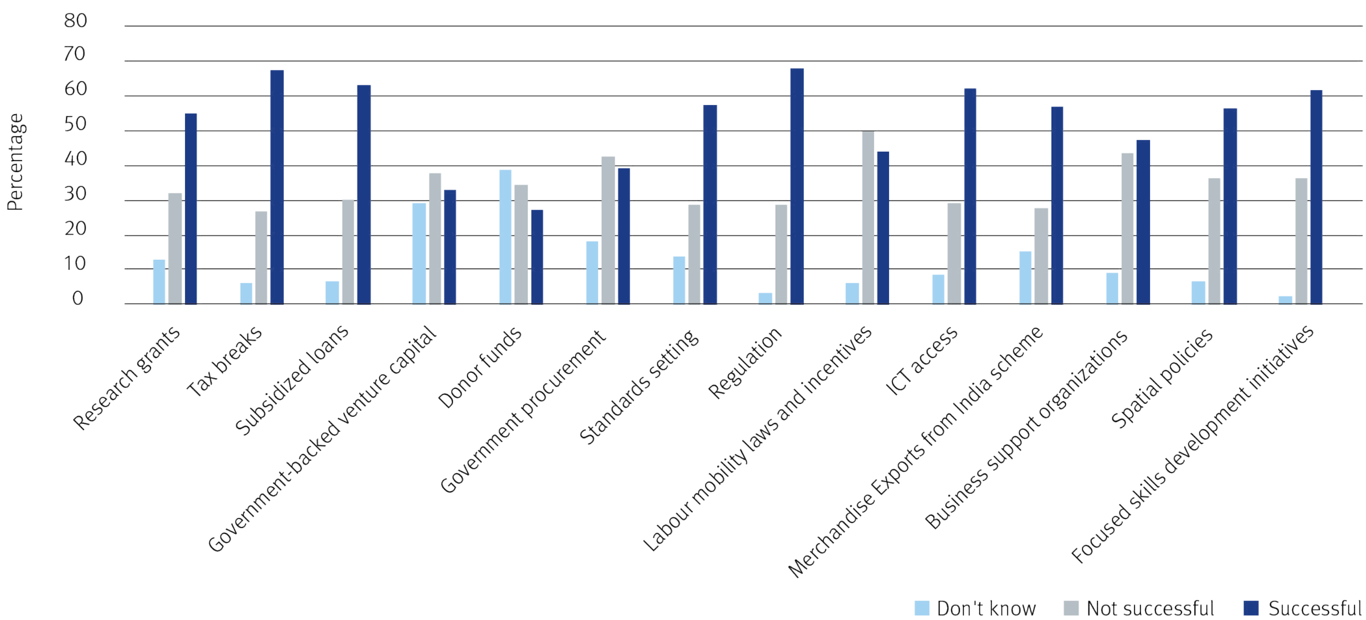
It is clear that the majority of the respondents see the supply side financial measures, 'Research grants' (100%) and 'Subsidized loans' (66.7%) as successful, along with the demand-side measure, 'Tax breaks' (66.7%). The role of arbitrageurs in the innovation process as well as their specific contribution through funding ideation to market would explain this. Venture capital plays a huge role in the commercialisation of scientific findings and facilitation of the emergence of high-growth businesses. They add value to the innovation ecosystem by fostering the generation, diffusion and absorption of new knowledge (Pierrakis & Saridakis, 2017). However, the emergence of **finance**-related barriers as reported by more than 85% of arbitrageur respondents possibly signals room for improvement.

Respondents also indicate demand-side measures such as 'Standards setting' (100%), 'Spatial policies' (100%) and 'Regulation' (66.7%) as successful which is convergent with the views of KBIs and intermediaries. The success of 'Standards setting' with respect to the automotive sector has been explained above. In the case of 'Spatial policies', it is clear that a high concentration of arbitrageurs can be seen within the financial hub of Maharashtra. The role of proximity is crucial within the venture capital industry (Zook, 2004). However, only 21% arbitrageurs engage with each other through 'Formal meetings' and 'Seminars' and only 14% through 'Informal meetings' and 'Joint research'.

In the case of 'Regulation', clear financial guidelines and regulations exist for arbitrageurs in India such as the SEBI (Alternative Investment Funds) Regulations, 2012 (the AIF Regulations) with respect to their functioning and investments (SEBI, 2012).

Summarising the above results, the most unsuccessful policy instruments (as depicted in Figure 32) reported by all actors are 'Labour mobility laws and incentives' (47.7%), followed by 'Business support organizations' (42.5%) and 'Govt procurement' (40.8%).

Figure 32. Success of Policy Instruments - All Actors



8.

Recommendations

Recommendations

Literature on innovation policy draws attention to the complex and heterogeneous nature of the policy instruments at hand. It captures the growing interest in understanding the effects that different policy instruments have on innovation performance, how (combinations of) individual instruments interact with market mechanisms and the overlapping or complementary effects that can be associated with different policy instruments within systems of innovation (Borrás and Edquist 2013; Izsák, Markianidou, and Radošević 2013; Mohnen and Röller 2001). This diversity reflects the complexity of innovation systems which entail a series of elements or sub-systems 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 to (Borrás and Edquist 2015):

- Support investment in research and innovation.
- Enhance the innovation competences of firms.
- Increase the adoption of Industry 4.0 (I4.0) through digital transformation in the automotive 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 automotive into global value chains (GVCs).
- Strengthen linkages within innovation systems.

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

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

The possibility of combining policy instruments is what makes innovation policy systemic (Borrás and Edquist 2013). However, finding 'optimal models' for the combination of instruments, otherwise interpreted as one-size-fits-all solutions, is problematic; significant differences result from framework conditions but also from the 'quality' of implementation (Flanagan, Uyarra, and Laranja 2011), the degree of maturity reached by certain agents or the innovation system as a whole (Izsák, Markianidou, and Radošević 2013), and even the particular governance structures around innovation (Dutrénit et al. 2010). Moreover, identifying the impacts of individual innovation policy interventions on social and economic outcomes is extremely difficult. There is a complex chain of direct and indirect, vertical and horizontal effects, and the ultimate results may only be visible 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 11 highlights short-, medium- and long-term recommendations based on the analysis conducted.

Table 11: Policy Recommendations

OBSERVATION	IMPLICATION	RECOMMENDATIONS
Fragmented system-wide actor information.	Better access of public goods in order to have an up-to-date understanding of who's who and who's where in the IASSI.	Need to integrate and standardise national actor databases with respect to the IASSI. • Review and consolidation of existing data. • Regularly update centralised sectorial database. • Purpose-driven platform to be developed in PPP approach beyond search engine (e.g., Startup India, IRCTC - Indigo). • To be owned by government and managed by institutions with access by all major institutions (market-driven). • Integrated feedback mechanism for improvement (stakeholders at all levels).
Need to improve target response rate, especially in the case of government actor group.	Better clarity in systems analysis for evidence-based policy craft incorporating longitudinal benefits of data collection.	• Institutionalise the IASSI Survey within a national institution with a top- down mandate. • Make the IASSI Survey and Report a mandatory census (4 years) and linked to the national database. • Targeted promotion strategy (including use of multimedia and social media, dissemination of value information, creation of ownership, multiple level campaign. • Actor or entity (state level, districts level,etc) level competition for response rate. • Incentiviszation 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 sensitiszation approach.

OBSERVATION	IMPLICATION	RECOMMENDATIONS
Need for better institutional coordination between regions / clusters.	Ease of skills and knowledge flow between and sharing of best practisespractices 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 (TBD);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 equally. • Make use of middle level executives (e.g., For example Linkedin Ccreator Aaccelerator Pprogramme)(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. • Standardisation of terminology used in policy/ national documentation. • Outreach to industry via industry associations. • Development of impact- driven, byyte size content dealing with core terminology and widely disseminated using multimedia in multiple languages(languages (30 sec short).
Lack of understanding by actors of each other's role within the IASSI.	Clear understanding of actor roles and responsibilities within a system with increased ability for them to reach out to each other. With the focus being the impact on the directionality of actor relationships to become more bi-directional.	• SSI should be an integrated component of national events, i.e. ACMA Southern Regional 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 safe (moral of the story). • Learn, un-learn, and thinkers and be future relevant.

OBSERVATION	IMPLICATION	RECOMMENDATIONS
		• Culture of iInnovation (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, startup kits).
Industry modes of interaction that require attention: **Intra:** Despite channels of communication between IND actors, there is low conversion into joint activities such as research that can lead to innovation. **Inter:** **IND - GOV** Poor public financing for the automotive sector. **IND - KBI** Low uptake of human capital from KBIs through 'Recruitment' or 'Secondments'. **IND-ARB** Firms have more than one relationship with multiple banks as recipients of funding.	Low innovation activities in the automotive sector due to lack of public funds for iIndustry. Formal and informal engagement with KBIs needs to translate into the absorption, by iIndustry, of skilled human capital leading to job creation.	**IND-IND** • Consortia work for undertaking pre-competitive work. (Working towards identifying the common problem, Size India, for example: human body dimensions, EV charging stations, road profile data acquisitions). • Standardisation for communication protocols for connected vehicles. • Promotion of solutions towards net zero. • Promotion of standardisation for circularity (e.g., end-of-life protocols -battery, engines, entire vehicles). • Think of incentives. • More schemes should be added in line with FAME and PLI. • Affordable, centralised research and testing facilities for MSMEs and startups. **IND-KBI** • Internship programme on the Technology Innovation Platform under the aegis of MHI and National. • Apprenticeship Promotion Scheme to be scaled up. • Development of centralised resources for internship programme spearheaded by ACMA, ARAI and SIAM. Link this to NIRF ranking. • Improving the employability index of higher education institutions. • Customisation of Quality Packs for the automotive sector addressing emerging technologies (e.g., CASE, ADAS, cyber security, functional safety).

OBSERVATION	IMPLICATION	RECOMMENDATIONS
		• Reskilling and upskilling of industry professionals (e.g., from ICE vehicles to EVs). • Evaluation of existing online courses and ranking of the same in line with industry relevance and assigning an industry champion to promote them. **IND-ARB** • Educating financial institutions and their assessors in line with new technological trends. For example, ARAI training insurers in emerging automotive topics.
Knowledge-based institutions modes of interaction that require attention: **Intra:** Few linkages in the form of joint research, formal meetings, informal meetings, seminars, and recruitment activities with respect to the automotive sector. **Inter:** **KBI-IND** Few linkages through joint research and co-publishing. **KBI-GOV** Poor linkages in terms of joint research and as recipients of funding. **KBI-INT** **Few joint research activities.**	KBIs are working in silos. Impacts on generation of applied research.	**Intra** • Create forums where KBIs (higher education institutions) come together on a regular basis. • Create formal forums for joint research, formal meetings, informal meetings, seminars, and recruitment activities with respect to the automotive sector. • Better coordination between departments and specialised centres within the institution. • Change in management outlook to better facilitate coordination. • Credit transfer between institutions should be allowed. • Research scholar exchange programmes should be initiated. • Replication of CSIR's Theme Directorate model for the automotive sector. **Inter KBI-IND** • Replicate the FITT Foundation for Information and Technology Transfer (IIT-D) model in other tertiary education institutions. • Providing adequate resources for functional spaces like dean of corporate relations for higher educational institutes. • Facilitating publishing of industrial research from point of view of IPR and other legalities.

OBSERVATION	IMPLICATION	RECOMMENDATIONS
		• Globally competitive packages to be made available to students graduating from core branches of engineering. • Involving industry in content and design of curriculum. • Introduction of convergence of disciplines at the beginning of post grad level. **KBI-GOV** • Unified platform with common criteria/template for application for funded research projects (e.g., SERB CRG, SURA, IRPHA, CHT, IMPRINT, CPS -funding platforms for energy storage technology). Multiple simultaneous projects should be encouraged. • Establish rigorous criteria for accountability and performance. • For government-led research grant/funding there needs to be coordination amongst various ministries. • Practices of NITI Aayog to be on par with framework programmes (FPs) of the EU. • From vision to application approach to be adopted (e.g., Horizon 2021 - UK Auto Drive programme). **KBI-INT** • Replication of models, such as Robert Bosch Technology Centre, Warwick Manufacturing Group, Fraunhofer institute – Industry-specific centres where you have representation of various intermediaries, fostering an aggregated approach to research. • Creation of good programme managers with a helicopter view of the sector. • 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.

OBSERVATION	IMPLICATION	RECOMMENDATIONS
Intermediary modes of interaction that require attention: 1. Long-term roadmap for fuel regulations and how it will facilitate the growth of the auto sector. 2. Highlighting the need for incentivisation of the automotive industry's innovation. Push for going beyond the regulatory requirements. **Intra:** Limited joint research and co-publishing activities. **Inter:** **INT-IND** Few joint research and co-publishing activities. **INT-GOV** Few linkages as recipients of funding, joint research, and co-publishing.	In the absence of a clear roadmap, we have to work on multiple technologies. Future proofing trends in the automotive sector. Lack of codification of knowledge together with industry.	• Working collectively and collaboratively. • Creation of a joint forum across intermediaries to discuss the topic of "Beyond Regulations". Utilising technology foresight model. **Intra** • Scale up joint research activities between intermediaries (e.g., ACMA, SIAM, ARAI) in line with the finding of technology foresight exercise. • Widening the scope of actor inclusion in such exercises. For example, new members and new institutions (CII, FICCI, NASSCOM) due to lateral application interdisciplinarity. **Inter** **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 industries to address topics related to circular economy, net zero, recycling, etc. **INT-GOV** • Widening the scope and scale of research activities through triangulation with other intermediaries and various government agencies taking into consideration their respective USPs and to leverage mega funding opportunities to address wider scale challenges of the sectors.
Arbitrageurs modes of interaction that require attention: Low reporting of linkages by arbitrageurs.	• Arbitrageurs are isolated as actors, and they can't perceive the importance of their own role in the automotive sector.	• Have regular fora addressing the areas of future technology trends skills and with inclusion of other system actors.

OBSERVATION	IMPLICATION	RECOMMENDATIONS
Intra: Few interactions through formal and informal meetings, seminars and as recipients of funding. **Inter:** Overall, there are few linkages with other actors.	• Arbitrageurs need to readjust their focus away from services to the manufacturing sector.	• Creating a pool of funds to support studies and activities pertaining to future technology trends and transformation of the automotive sector. Thus, enabling them to better assess the risk and returns of the future of investment in the sector. • Promotion of corporate venture capital funds led by the leaders of the automotive sector. Following the lead of CVCs in other sectors (e.g., TATA STEEL and MARICO).
Barriers to innovation - Industry: • **Policy:** 'Lack of clear national innovation strategy' and 'Lack of explicit policy support' • **Technology infrastructure:** 'Lack of technology (technology gap)' and 'Lack of infrastructure for I4.0' • **Finance:** 'Innovation costs (too high)', 'Lack of finance', 'Excessive perceived economic risk' and 'Cost of I4.0 technologies'. • **Human resources:** 'Quality of technically trained manpower'.	• Innovation is not the purview of one ministry alone and that it is an all of government approach. • Existing policies are not reaching their target audiences. • Effective data capture and transmission is not taking place leading to lack of transparency. • Continuing "business as usual" and thus hampering innovation.	**Policy** • Distilled versions of policies and strategies need to be articulated and disseminated. • OEMs and Tier 1's should be actively percolating policy information down the value chain. • Development of a common, single integrated document pertinent to technology and innovation in the automotive sector, derived from national policies and strategies, and authored, regularly reviewed and disseminated by intermediaries (e.g.,SIAM, ARAI, ACMA). • Use platforms like SIAM, ACMA and national conventions for dissemination of policy information. • Samarth programme is to be scaled up. **Technology** • Work with telecommunication companies to develop packages for IoT connectivity. • Working with the IT sector to develop platforms for data consolidation, standardisation and analytics and dissemination. • Economies of scale with localisation of hardware and software supply. **Finance** • Raising awareness of financial schemes among the industry players such as MSME Technology Acquisition Development Fund. • Clear cut financial mechanisms promoting innovation need to be introduced for the sector.

OBSERVATION	IMPLICATION	RECOMMENDATIONS
		• Dissemination of case study approach dealing with risk, overcoming failure, and successes. • Promoting collaboration among industry players for reducing risk. **Human Resource** • Intermediates running curriculum programme in association with KBIs and industries, for example ARAI. • Evaluation ranking and promotion of relevant online courses for the automotive sector. • Mapping of required skill sets in JD to specific course requirements from an academic point of view. • With the triangulation approach industry, intermediary and KBI development of structured internship programmes with a focus on practical solutions.
Barriers to innovation - KBIs: • **Finance:** 'Innovation costs (too high)' • **Human resources:** 'Lack of technically trained manpower' and 'Quality of technically trained manpower'.		**Human resources** • Increase the reach of faculty development programmes. • Promotion of faculty exchange and rotation programmes. • Creating programmes like Senior/ Experts Service programme (a volunteering programme in Germany). • Upscaling of TEQIP,CEP and QIP programmes
Barriers to innovation - Intermediary: • **Policy:** 'Lack of clear national innovation strategy' and 'lack of explicit policy support'. • **Finance:** 'Excessive perceived economic risk' and 'Cost of I4.0 technologies'. • **Technology infrastructure:** 'Lack of infrastructure for I4.0', 'Lack of technology (technology gap)', 'Lack of access to I4.0 technologies' and 'Lack of understanding of I4.0 technologies'.		**Policy** • Distilled versions of policies and strategies need to be articulated and disseminated. • Forecasting the scale of intervention required with one CFC per state or per district; implementation can be done using PPP model. **Finance** • Economies of scale with localisation of hardware and software supply.

OBSERVATION	IMPLICATION	RECOMMENDATIONS
		• Clear cut financial mechanisms promoting innovation need to be introduced for the sector. • Dissemination of case study approach dealing with risk, overcoming failure, and successes. • Promoting collaboration among industry players for reducing risk. **Technology infrastructure** Creation of network/platform for transfer of technology, I4.0 programmes. • Scaling up of C4I4, PSG College of Technology, and SAMARTH Udyog Centre.
Barriers to innovation - Arbitrageurs • **Finance:** 'Lack of finance' • **Human resources:** 'Quality of technically trained manpower' and 'Lack of technically trained manpower' • **Management:** 'Hierarchical organizations', 'Lack of higher resolution regulations' and 'Organizational rigidities' • **Technology infrastructure:** 'Lack of traditional infrastructure'.		Finance, human resources and technology infrastructure (see above). **Management** • Innovation indicator assessment schemes should be adopted and should include parameters to assist dissemination of knowledge across actors/stakeholders. • Cascading mentoring scheme. • Rolling strategic plan for entire organization. • Adoption of knowledge management systems (e.g., Wikis). • Common engineering facilities focusing on specific domains should be scaled up.
Latent barriers - North India • Lack of Industry 4.0 readiness. • Undynamic markets. • Lack of resources and capabilities.		• Scaling up of C4I4, PSG College of Technology, SAMARTH Udyog Centre. • SIAM, ACMA to join forces with SAMARTH Udyog Centre to disseminate to the automotive sector. • Increasing outreach of ASDC skilling programme. • Application of readiness index and benchmarking indices for I4.0. • Offering mandatory I4.0 module in automotive engineering. • Forecasting scale of intervention required linked to national automotive programme strategies with one CFC per state or per district; implementation can be done using the PPP model.

OBSERVATION	IMPLICATION	RECOMMENDATIONS
Latent barriers - South India: • Lack of Industry 4.0 readiness • Inflexibility and poor human capital retention • Poor human capital • Undynamic markets		• Clear definition of career paths including rotation with innovative designation. • Competitive compensation packages to be offered. • Aim for creation surplus skilled human capital. • Proficiency assessment programmes have to be created and applied across all sectors. • Transition towards gig economy approach (learn-unlearn-reskill). • Staying relevant and agile through, leadership and culture strategy development, leadership assessment, drive behaviour changes, changing behavior and developing the capabilities of managers within the sector. • Adopting model of IT sector creating skilled human capital pipeline and bench. • Adoption of crowdsourcing and co-creation as a problem-solving tool.
Unsuccessful policy instruments from the perspective of industry: • 'Labour mobility laws and incentives' • 'Govt-backed venture capital' • 'Govt procurement'	Strengthen and focus delivery of policy to address specific gaps.	• Moving towards technology-based work solutions. • Adoption of softLanding platforms, such as Vahan and Digilocker, for people migrating across regions. • Build awareness of government-backed funding schemes. • Creating awareness of best practices and successes. of already implemented government procurement platforms (GEM portal). • Structuring, filtering and dissemination of information related to government procurement and demand-side policy incentives.
Unsuccessful policy instruments from the perspective of KBIs: • 'Merchandise Exports from India Scheme'. • 'Business support organizations'. • 'Labour mobility laws and incentives'.	Strengthen and focus delivery of policy to address specific gaps.	• Re-evaluation of RoDTEP Scheme. • Creating an effective system to have faster access with export credits (pre-shipment and post-shipment). • Establish strategic network between KBI & MSME tool rooms for up gradation, development and supply of advanced technologies.

OBSERVATION	IMPLICATION	RECOMMENDATIONS
		• Creation of strategic facilitation unit within KBIs to oversee international best practices/tooling programmes; this can be embedded at the regional level. • Strengthen/incentivise sabbatical leave/ secondments for increasing knowledge translation. • Result-based incentives to faculty for engagement with industry. Promotion of mutual benefits.
Unsuccessful policy instruments from the perspective of intermediaries: • 'Subsidised loans'	Strengthen and focus delivery of policy to address specific gaps.	• Create databases on the impact of and the beneficial effects of startup subsidies. • Creating a mechanism to establish linkage/interplay between public subsidies and private financing. Development of a bridging fund. • Cascade follow-on financing from subsidized loans.
Unsuccessful policy instruments from the perspective of arbitrageurs: • 'Labour mobility laws and incentives' • 'Business support organizations' • 'Focused skills development initiatives'		• Strengthening corporate governance laws in startups, to foster a good advisory board for startups including experts from industry, academia, etc. • Incentivise VC's/angel investors to collaborate with regional incubators for investor readiness training programmes and creating local angel networks. • Scaling -up of programmes like 'Startup InvestOpreneur' by IIM Lucknow Incubator for training new investors on early-stage investments

9.

References

References

Agrawal, M., Eloot, K., Mancini, M. & Patel, A. (2020) Industry 4.0: Reimagining manufacturing operations after COVID-19. McKinsey. 29 July. Available from: https://www.mckinsey.com/business-functions/operations/our-insights/industry-40-reimagining-manufacturing-operations-after-covid-19 [Accessed 28th August 2021.]

Alexander, A., Martin, D.P., Manolchev, C. & Miller, K. (2020) University–industry collaboration: using meta-rules to overcome barriers to knowledge transfer. Journal of Technology Transfer, Springer Verlag. 45 (2), pp.371-392. Available from: University–industry collaboration: using meta-rules to overcome barriers to knowledge transfer (archives-ouvertes.fr) [Accessed 20th June 2021].

Ambos, B., Brandl, K., Perri, A., Scalera, V.G. & Assche, A.V. (2021) The nature of innovation in global value chains. Journal of World Business. 56 (4), Available from: https://doi.org/10.1016/j.jwb.2021.101221 [Accessed 5th October 2021].

Amirapu, A. & Gechter, M. (2020) Labour Regulations and the Cost of Corruption: Evidence from the Indian Firm Size Distribution. The Review of Economics and Statistics. MIT Press, vol. 102(1), pages 34-48, March. Available from: (PDF) Labor Regulations and the Cost of Corruption: Evidence from the Indian Firm Size Distribution (researchgate.net) [Accessed 8th October 2021].

Antony, A. (2021) History of Electric Vehicles in India. Available from: History of Electric Vehicles in India (getelectricvehicle.com) [Accessed 18th October 2021].

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 2021].

Atal Innovation Mission (2020) About Atal Innovation Mission. Available from: https://aim.gov.in/overview.php› [Accessed 18th May 2020].

Atal Innovation Mission (2020) Atal New India Challenge. Available from: https://aim.gov.in/atal-new-india-challenge.php [Accessed 18th May 2020].

Atal Innovation Mission (2019) Summary of Selection of Grantees for Atal New India Challenge. Available from: https://aim.gov.in/ANIC_1.0_SSC_Selection_Summary.pdf [Accessed 18th May 2020].

Automotive Component Manufacturers Association (2021) About. Available from: About the Automotive Component Manufacturers Association of India - ACMA [Accessed 15th June 2021].

Automotive Skills Development Council (2020) About us. Available from: https://www.asdc.org.in/about-us#vision [Accessed 18th May 2020].

Automotive Skills Development Council. Partnership Opportunity. Available from: https://www.asdc.org.in/skilldevelopment [Accessed 18th May 2020].

Ballantyne, C. (2004) Online or on paper. An examination of the differences in response and respondents to a survey administered in two modes. Paper presented at the Australasian Evaluation Society 2004 International Conference, Adelaide, South Australia. Available from: Microsoft Word - FR21-Ballantyne, C.doc (websm.org) [Accessed 24th June 2021].

Bapat, S., A. Chaturvedi, W. Drewery, F. Fei and E. Hepfer (2012) Tamil Nadu Automotive Cluster. Microeconomics of Competitiveness. Harvard Business School. Spring. Available from: https://www.isc.hbs.edu/Documents/resources/courses/moc-course-at-harvard/pdf/student-projects/MOC%20Tamil%20Nadu%20Auto%20Cluster%20Final.pdf [Accessed 25th May 2020].

Bartels, F. & Koria, R. (2012) The Ghana National System of Innovation Measurement, Analysis & Policy Recommendations. The United Nations Industrial Development Organization (UNIDO). Available from: layout7.indd (unido.org) [Accessed 25th May 2021].

Bartels, F. & Koria, R. (2015) The Kenya National System of Innovation Measurement, Analysis & Policy Recommendations. The United Nations Industrial Development Organization (UNIDO). Available from: layout9.indd (unido.org) [Accessed 25th May 2021].

Bartels, F., Voss, H., Bachtrog, C., & Lederer, S. (2012) Determinants of National Innovation Systems: Policy Implications for developing countries. Innovation Management Policy and Practice, 14(1), pp. 2-18.

Bawase, M. A. ., & Thipse, D. S. S. (2021). Impact of 20% Ethanol-blended Gasoline (E20) on Metals and Non-metals used in Fuel-system Components of Vehicles . ARAI Journal of Mobility Technology, 1(Inaugural), pp1–8. https://doi.org/10.37285/ajmt.1.0.1 (Original work published October 1, 2021).

Baygan, G. & Freudenberg, M. (2000) The internationalisation of venture capital activity in OECD countries: Implications for measurement and policy. OECD Science, Technology and Industry Working Papers 2000/7, Paris, OECD.

Bergek, A., Hekkert, M.P. & 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: T., Foxon, J., Kohler, and C. Oughton (eds.) Innovations for a Low Carbon Economy: Economic, Institutional and Management Approaches. Cheltenham, Edward Elgar.

Bernstein, L. (2015) Beyond Relational Contracts: Social Capital and Network Governance in Procurement Contracts. Journal of Legal Analysis. 7 (2), pp. 561–621. Available from: https://doi.org/10.1093/jla/law001 [Accessed 25th August 2021].

Berrens, R.P., Bohara, A.K., Jenkins-Smith, H., Silva, C., & Weimer, D.L. (2003) The advent of internet surveys for political research: A comparison of telephone and internet samples. Political Analysis, 11(1), pp. 1-22.

Bhargava, Y., Words don’t help sales, need action from govt, says R.C. Bhargava. The Hindu, Available at: https://www.thehindu.com/business/Industry/words-dont-help-sales-need-action-from-govt-says-r-c-bhargava/article36095370.ece [Accessed 25th September 2021].

Bodas Freitas, I. M., & Rossi, F. & Geuna, A. (2013) Collaboration objectives and the location of the university partner: Evidence from the Piedmont region in Italy. Papers in Regional Science. doi:10.1111/pirs.12054.

Boer, E., George, K., & 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].

Bogers, M., Bekkers, R., & Granstrand, O. (2012) Intellectual property and licensing strategies in open collaborative innovation. In: C. de Pablos Heredero & D. López (eds.) Open Innovation at Firms and Public Administrations: Technologies for Value Creation, pp. 37-58. Hershey, PA: IGI Global.

Boldrin M., Levine D.K. (2008) Intellectual Property. In: Palgrave Macmillan (eds.) The New Palgrave Dictionary of Economics. Palgrave Macmillan, London. Available from: https://doi.org/10.1057/978-1-349-95121-5_2546-1 [Accessed 25th August 2021].

Borras, S., and Edquist, C. (2013) The choice of innovation policy instruments. Technological Forecasting and Social Change, 80, pp. 1513- 1522.

Borras, S., and Edquist, C. (2015) Competence Building: A Systemic Approach to Innovation Policy. In The Economics of Knowledge, Innovation and Systemic Technology Policy, edited by Francesco Crespi and Francesco Quatraro, 361–84. New York: Routledge.

Bozeman, B. (2000) Technology Transfer and Public Policy: A Review of Research and Theory. Research Policy 29(4-5): 627-655.

Breschi, S., and Malerba, F. (1997) Sectoral systems of innovation: technological regimes, Schumpeterian dynamics and spatial boundaries. In: Edquist, C. (eds.), Systems of Innovation: Technologies, Institutions and Organizations, Frances Pinter, London, 130–155.

Broström, A. & Mckelvey, M. (2015) Universities and Public Research Institutes as Collaboration Partners. 10.4337/9781783477326.00009.

BTG Legal (2021) Public procurement in India: Risks and challenges inherent in supplying to the Government. Available at: Public Procurement in India Risks and challenges inherent in supplying to the government – Legal Developments (legal500.com) [Accessed 8th October 2021].

Buciuni, G. and Pisano, G. (2021) Variety of innovation in global value chains. Journal of World Business. Elsevier, 56(2). Available from: Variety of Innovation in Global Value Chains - ScienceDirect [Accessed 15th October 2021].

Cai, Y., & 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 15th October 2021].

Carlsson, B. (2016) Industrial Dynamics: A Review of Literature 1990 – 2009. Industry and Innovation, Vol. 2716, pp. 1–62.

Carlsson, B. and Stankiewicz, R. (1991) On the nature, function and composition of technological systems.

Journal of Evolutionary Economics, Vol. 1 No. 2, pp. 93– 118.

Cavalcante, S., Kesting, P., Ulhøi, J. (2011) Business model dynamics and innovation: (re)establishing the missing linkages. Management Decision, Vol. 49, Issue: 8, pp.1327-1342. Available from: https://doi.org/10.1108/00251741111163142. [Accessed 24th June 2021].

Chaliawala, N. (2021) EV Push: FAME-II scheme achieves just 10% target with 4 months left in original deadline. The Economics Times. Available from: EV Push: FAME-II scheme achieves just 10% target with 4 months left in original deadline - The Economic Times (indiatimes.com) [Accessed 10th October 2021]

Chaliawala, N. and Thakkar, K. (2022) Mercedes-Benz to assemble EVs in India starting this year. The Economics Times. Available from: Mercedes-Benz to assemble EVs in India starting this year - The Economic Times (indiatimes.com) [Accessed 30th January 2022]

Chaminade, C., Lundvall, B.Å. & Haneef, S. (2018) Advanced Introduction to National Innovation Systems. Cheltenham: Edward Elgar.

Chappin, M. M. H., Hekkert, M. P., Meeus, M. T. H. & Vermeulen, W. J. V. (2008) The intermediary role of an industry association in policymaking processes: The case of the Dutch paper and board industry. Journal of Cleaner Production, 16: 14, 1462–73. Available from: doi:10.1016/j.jclepro.2007.08.004 (uvt.nl) [Accessed 25th June 2021].

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 and Sustainable Development, vol. 13, pp. 15-36. Available from: Thailand_Food_Institute-with-cover-page-v2.pdf (d1wqtxts1xzle7.cloudfront.net) [Accessed 25th June 2021].

Clason, D.L. & Dormody, T.J. (1994) Analyzing Data Measured by Individual Likert-Type Items. Journal of Agriculture and Education, 35(4), pp. 4-35.

Cobanoglu C., Warde, B., & Moreo, P.J. (2001) A comparison of mail, fax and web-based survey methods. International Journal of Market Research, 43(4), pp. 441–452.

Cohen, W.M. and Levinthal, D.A. (1990) Absorptive Capacity: A New Perspective on Learning and Innovation. Administrative Science Quarterly, Vol. 35 No. 1, pp. 128–152.

Confederation of Indian Industry (2013) Union Budget 2013-14, An analysis. Delhi. Available from: https://cii.in/WebCMS/Upload/Budget%20Analysis%202013-14.pdf [Accessed on 22nd May 2020].

Cooke, P., Uranga, M.G. and Etxebarria, G. (1997) Regional innovation systems: Institutional and organisational dimensions. Research Policy, Vol. 26, pp. 475– 491.

Cornell University, INSEAD, and WIPO (2015) The Global Innovation Index 2015: Effective Innovation Policies for Development. Fontainebleau, Ithaca, and Geneva.

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

Dalenogare, L.S., Benitez, G.B., Ayala, N.F. & 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 2021].

De Leeuw, E.D. (2009) Choosing the Method of Data Collection. In: de Leeuw, E.D., Hox. J.J., and Dillman. D.A. (2009) International Handbook of Survey Methodology. Psychology Press. New York. Chapter 7.

De Leeuw, D.E., Hox, J.J. & Kef, S. (2003) Computer-Assisted Self Interviewing tailored for special populations and topics. Field Methods. 15(3), pp. 223-251.

De Giovanni, Pietro & Cariola, Alfio. (2020). Process innovation through industry 4.0 technologies, lean practices and green supply chains. Research in Transportation Economics. Available from: https://doi.org/10.1016/j.retrec.2020.100869 [Accessed 20th June 2021].

Deloitte (2018a) Toward the next horizon of Industry 4.0. Accelerating transformation through collaboration and startups. Available from: IL327_Toward-the-next-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: 74d8a3d1-4ade-4196-889d-044e47c5d93c (admiralcloud.com) [Accessed 20th September 2021]

Ministry of Heavy Industry (2006) AUTOMOTIVE MISSION PLAN 2006-2016. New Delhi. Available from:

https://www.MHI.nic.in/writereaddata/Content/Automotive%20Mission%20Plan%20(2006-2016).pdf [Accessed 11th May 2020].

Ministry of Heavy Industry (2013) National Electric Mobility Mission Plan 2020. New Delhi. Available from: https://MHI.nic.in/writereaddata/Content/NEMMP2020.pdf [Accessed 12th May 2020].

Ministry of Heavy Industry (2016) Office Memorandum. New Delhi. Available from: https://MHI.nic.in/writereaddata/UploadFile/office%20memorandum.pdf [Accessed 19th May 2020]

Ministry of Heavy Industry (n.d.) Automotive Industry/ Development Council (DCAAI). Available from: https://MHI.nic.in/UserView/index?mid=1402 [Accessed 16th May 2020].

Ministry of Heavy Industry (n.d.) Automotive Industry/ R&D Projects under DCAAI. Available from: https://MHI.nic.in/UserView/index?mid=2477 [Accessed 16th May 2020].

Ministry of Heavy Industry (2016) Final Draft Automotive Mission Plan 2016-26. New Delhi. Available from: https://MHI.nic.in/writereaddata/Content/AMP%20 2016-26%20Final%20Approved%20Draft.pdf [Accessed 11th May 2020].

Ministry of Heavy Industry (2019) Faster Adoption and Manufacturing of Electric Vehicles in India Phase II (FAME India Phase II) Notifications & Guidelines. New Delhi. Available from: https://MHI.nic.in/writereaddata/UploadFile/publicationNotificationFAME%20II%208March2019.pdf [Accessed 13th May 2020].

Department of Science and Technology (2020) Science, Technology, and Innovation Policy. Draft STIP Doc 1.4. Available from: Microsoft Word - STIP_Doc_1.4_Dec2020.docx (dst.gov.in) [Accessed 5th May 2021].

MHIngra, M. (2020) India Auto Inc scrambles to skill its workforce. Autocarpro. 18 January. Available from: India Auto Inc scrambles to skill its workforce (autocarpro.in) [Accessed 26th August 2021].

Dillman, D.A. (1978) Mail and internet surveys: The tailored design method. New York: Wiley.

download?doi=10.1.1.201.7854&rep=rep1&type=pdf [Accessed 3rd May 2021].

Dutrénit, G., Mario, C., Juan, M. C., Martin, P., Fernando, S., & Alexandre, V. (2010) El Sistema Nacional de Innovación Mexicano: Estructuras, Políticas, Desempeño y Desafíos. Mexico, Montevideo: Universidad Autonoma Metropolitana, Textual. Available from: http://mpra.ub.uni-muenchen.de/31982/ [Accessed 19th June 2021].

Dzisah, J., & Etzkowitz, H. (2008) Triple Helix circulation: the heart of innovation and development. International Journal of Technology Management and Sustainable Development, 7(2), 101–115.

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

Easterby-Smith, M., Thorpe, R., & Jackson, P.R. (2012) Management Research Edition 4. London: Sage Publications.

Edler, J. & Georghiou, L. (2007) Public procurement and innovation – Resurrecting the demand side, Research Policy 36, 949-963.

Edquist, C. (1997) Introduction. Systems of Innovation: Technologies, Institutions, and Organisations, pp. 1–35.

Edquist, C., & Hommen, L. (1999) Systems of innovation: theory and policy for the demand side. Technology in Society, 21(1), pp. 63-79.

Edwards-Schachter, M., Anlló, G., Castro-Martínez, E.,Sánchez Barrioluengo, M., & Lucio, I. (2012) Motives for Inter-Firm Cooperation on R&D and Innovation: Empirical Evidence from Argentine and Spain.

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

Energysage (2021) How do electric car batteries work? Available from: How Do Batteries For Electric Cars Work? | EnergySage [Accessed 4th September 2021].

ET Auto Bureau (2015) Five key points in the new Foreign Trade Policy that matters to the auto part makers. The Economic Times. Available from: https://auto.economictimes.indiatimes.com/news/auto-components/five-key-points-in-new-foreign-trade-policy-that-matters-to-the-auto-part-makers/46793003 [Accessed 12th May 2020].

ET Online (2021) Government approves PLI scheme for auto and drone sector, offers incentive worth Rs 26,058 crore. Sep 15. Available from: Government approves PLI scheme for auto and drone sector, offers incentive worth Rs 26,058 crore - The Economic Times (indiatimes.com) [Accessed 20th August 2021].

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 & Sustainable Development. 1(1), pp. 7–20.

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. New York: Routledge.

Etzkowitz, H. (2017) Innovation Lodestar: The entrepreneurial university in a stellar knowledge firmament. Technological Forecasting and Social Change, 123(4), pp. 122–129.

Etzkowitz, H. & 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. & 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, pp. 109-123.

EV Reporter (2021) India's Electric Vehicles Sales Trend for 2021. Available from: India's Electric Vehicle Sales Trend for 2021 • EVreporter [Accessed 20th January 2022].

Fagerberg, J. (2016) Innovation Policy: Rationales, Lessons and Challenges. Journal of Economic Surveys, 31(2), pp. 497–512.

Etzkowitz, H., Webster, A., Gebhardt, C. & Cantisano Terra, B. R. (2000) The future of the university and the university of the future: Evolution of ivory tower to entrepreneurial paradigm. Research Policy, 29, pp. 313-330.

Fagerberg, J., and Srholec, M. (2008) National innovation systems, capabilities and economic development. Research Policy, 37(9), pp. 1417-1435.

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

FDI INDIA (2021) Home/Sectors/Automobile, 'Investment in Automobile Industry in India'. Available from: https://www.fdi.finance/sectors/automobile [Accessed 28th May 2021].

FICCI and Roland Berger (2016) Skill Development for Industry 4.0. Available from: http://www.globalskillsummit.com/whitepaper-summary.pdf [Accessed 1st June 2020].

FICCI, NASSCOM and EY (2017) Future of Jobs in India-A 2022 Perspective. Available from: http://ficci.in/spdocument/22951/FICCI-NASSCOM-EY-Report_Future-of-Jobs.pdf [Accessed 23rd May 2020].

Flanagan, K., Uyarra, E. & Laranja, M. (2011) Reconceptualising the 'policy mix' for innovation. Research Policy, 40(5), pp. 702-713.

Foray, D. (2004) The Economics of Knowledge. Cambridge, MA: MIT Press.

Foxon, T. (2003) Inducing Innovation for a low-carbon future: drivers, barriers and policies - A report for The Carbon Trust. The Carbon Trust, London.

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

Freeman, C., & Louca, F. (2001) As Time Goes By: From the Industrial Revolutions to the Information Revolution. Oxford: Oxford University Press.

Gajdzik, B., Grabowska, S. & Saniuk, S. A. (2021) Theoretical Framework for Industry 4.0 and Its Implementation with Selected Practical Schedules. Energies, 14, 940. Available from: https://doi.org/10.3390/ en14040940 [Accessed 3rd October 2021].

García-Sánchez, E., García-Morales, V., & Martín-Rojas, R. (2018) Influence of Technological Assets on Organizational Performance through Absorptive Capacity, Organizational Innovation and Internal Labour Flexibility. Sustainability. 10. 770. 10.3390/su10030770. Available from: (PDF) Influence of Technological Assets on Organizational Performance through Absorptive Capacity, Organizational Innovation and Internal Labour Flexibility (researchgate.net) [Accessed 30th August 2021].

Garland, R. (1991) The Mid-Point on a Rating Scale: Is it Desirable? Marketing Bulletin, 2(1), pp. 66-70.

Gaur, L. and Sahdev, S.L. (2015) Frugal innovation in India: The case of Tata Nano, International Journal of Applied Engineering Research, January.

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

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

Ghani, E. & Mishra, S. (2020) Closing the digital divide. Financial Express. Available from: https://www.

financialexpress.com/opinion/closing-the-digital-divide/2126724/ [Accessed 28th August 2021].

Government of Karnataka (2014) Karnataka Industrial Policy 2014-19. Available from: KARNATAKA INDUSTIRAL POLICY 2014-2019 (icmai.in) [Accessed 15th October 2021].

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].

Greenacre, P., Gross, R. and Speirs, J. (2012) Innovation Theory: A review of the literature. ICEPT Working Paper, No. May, p. Ref: ICEPT/WP/2012/011.

Hall, B.H. (2004) University-industry partnerships in the United States. In Contzen, J.-P., Gibson, D., & Heitor, M.V. (eds.), Rethinking science systems and innovation policies. Proceedings of the 6th international conference on technology policy and innovation. Ashland OH: Purdue University Press.

Hargadon, A.B. (1998) Firms as Knowledge Brokers: Lessons in Pursuing Continuous Innovation. California Management Review, 40(3), pp. 209-207.

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 analysing technological change. Technological Forecasting and Social Change, Vol. 74 No. 4, pp. 413–432.

Hemmert, M., Bstieler, L.,& Okamuro, H. (2014) Bridging the cultural divide: trust formation in university–industry research collaborations in the US, Japan, and South Korea. Technovation 34:605–616. Available from: https://doi.org/10.1016/j.technovation.2014.04.006 [Accessed 2nd May 2021].

Hermann, M., Pentek, T. and Otto, B. (2016) Design principles for industrie 4.0 scenarios. In 2016 49th Hawaii international conference on system sciences (HICSS), January. pp. 3928-3937). IEEE.

Herstatt, C. & Tiwari, R. (2014) Aiming big with small cars - The emergence of a lead market in India. ISBN 978-3-319-02066-2.

Hjort, J., and Poulsen, J. (2017) The Arrival of Fast Internet and Employment in Africa. NBER Working Paper No. w23582.

Holweg, M. and Oliver, N. (2016) Crisis, Resilience and Survival: Lessons from the Global Auto Industry. Cambridge: Cambridge University Press.

IAP (Indian Automotive Products) (2019) History. Available from: History Indian Automotive Products,Indian automobiles,car manufacturers,truck dealers,motorcycle,tractor,india (indian-automotive.com) [Accessed 25th June 2021].

ILO Consulting (2020) Subsidies within the Automobile Industry in India. Available from: Subsidies within the Automobile Industry in India (iloconsulting.in) [Accessed 10th October 2021]

India Brand Equity Foundation (IBEF) (2018) Automobile Companies in India. Available from: Automobile Companies in India, Top Car Manufacturers, Major Brands (ibef.org) [Accessed 25th June 2021].

India Brand Equity Foundation (IBEF) (2020) Maharashtra. Gateway to India. Available from: https://www.ibef.org/download/Maharashtra-March-2020.pdf [Accessed 20th May 2021].

India Brand Equity Foundation (IBEF) (2020) Indian Automobile Industry Analysis. TechSci Research and Indian Brand Equity Foundation. Available from: https://www.ibef.org/download/Automobiles-March-2020.pdf [Accessed 20th May 2020].

Invest India (2021) Invest in Indian Automobile Industry. Available from: Invest in Indian Automobile Industry, Auto Sector Growth Trends (investindia.gov.in) [Accessed 25th June 2021].

IOM (2021) Labour mobility and skills in response, recovery, and post covid-19 pandemic. Policy Brief. 27 January 2021. Available from: https://www.iom.int/sites/g/files/tmzbdl486/files/documents/policy_brief_labour_mobility_and_skills_in_covid_time_final_final_0.pdf [Accessed 6th October 2021]

Irudaya Rajan, S., Sivakumar, P., & Srinivasan, A. (2020) The COVID-19 Pandemic and Internal Labour Migration in India: A ‚Crisis of Mobility'. The Indian journal of labour economics : the quarterly journal of the Indian Society of Labour Economics, 1–19. Available from: https://doi.org/10.1007/s41027-020-00293-8 [Accessed 20th October 2021].

Isaksen, A. (2001) Building regional innovation systems: Is endogenous industrial development possible in the global economy?, Canadian Journal of Regional Science, 24, 101-124.

Ivanov, D., Dolgui, A., & Sokolov, B. (2019) The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics. International Journal of Production Research, 57(3), 829–846.

Izsák, K., Paresa, M., & Slavo, R. (2013) Lessons from a Decade of Innovation Policy: What Can We Learn from TrendChart and Innovation Union Scoreboard. European Union. Available from: http://www.know-hub.eu/blog/lessons-froma-decade-of-innovation-policy-what-can-we-learn-from-trendchart-and-innovation-union-scoreboard/impaired-0.html [Accessed 20th October 2021].

Jadhav, V. & Mahadeokar, R. (2019) The Fourth Industrial Revolution (I4.0) in India: Challenges & Opportunities. Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Special Issue | Fostering Innovation, Integration and Inclusion Through Interdisciplinary Practices in Management, March, pp.105-109, Available from: https://www.ijtsrd.com/papers/ijtsrd23076.pdf [Accessed 20th May 2021].

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

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

Kale, D. (2012) Sources of Innovation and Technology Capability Development in the Indian Automobile Industry. Institutions and Economies, 4 (2), pp 121-150.

Kaloudis, A., Aspelund, A., Koch, P. M., Lauvas, T. A., Mathisen, M. T., Strand, Ø., Sørheim, R., & Aadland, T. (2019) How Universities Contribute to Innovation: A Literature Review-based Analysis. Norwegian University of Science and Technology (NTNU). Available from: https://www.ntnu.edu/documents/1272711283/1276140112/Rapport_How+universities+contribute+to+innovation_web.pdf/86b6a699-0499-820e-0f52-35a7b7101de5?t=1574848729613 [Accessed 26th August 2021].

Karlsen, A., Lund, H.B. & Steen, M. (2022) The roles of intermediaries in upgrading of manufacturing clusters: Enhancing cluster absorptive capacity. Competition & Change. January. Available from: https://doi.org/10.1177/10245294211059138 [Accessed 30 January 2022].

Khan, A. N. (2021) Automotive PLI ignores the present; sets the agenda for future. September 16. Available from: pli scheme: Automotive PLI ignores the present; sets the agenda for future, Auto News, ET Auto (indiatimes.com) [Accessed 20th October 2021].

Kieft, A., Harmsen, R. & Hekkert, M.P. (2017) Interactions between systemic problems in innovation systems: The case of energy-efficient houses in the Netherlands. Environmental Innovation and Societal Transitions, Vol. 24, pp. 32–44.

Kim J.O., & 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. & Nelson, R. R. (2000) Technology, learning, and innovation: experiences of newly industrialized economies. Cambridge: Cambridge University Press.`

Kitchenham, B. & Pfleeger, S. L. (2002) Principles of Survey Research, Parts 1 to 6. Software Engineering Notes, 2001-2002.

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

Koria, R. (2019) Cabo Verde National System of Innovation. Measurement, Analysis and Policy Recommendations. The United Nations Industrial Development Organization.

Koria, R., Bartels, F. L., Koeszegi, S. & Carneiro, S. (2012) Free Open Source Software (FOSS) and Survey Methodologies: The case of the Ghana National System of Innovation Survey, IST Africa 2012 Conference Proceedings, Paul Cunningham and Miriam Cunningham (eds.), IIMC International Information Management Corporation.

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

Krishnan, T. R. (2016) The jump to BS-VI and what it means for innovation. Founding Fuel. Available from: The jump to BS-VI and what it means for innovation | Founding Fuel [Accessed 13th October 2021]

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

Kuhlmann, S. & Erik, A. (2001) RCN in the Norwegian

Research and Innovation System. Reports in the Evaluation of the Research Council of Norway: Background Reports. Karlsruhe: Fraunhofer-Institut für Systemtechnik und Innovationsforschung -ISI.

Labovitz, S. (1967) Some observations on measurement and statistics. Social Forces, 46 (December), pp. 151-160.

Labovitz, S. (1970) The assignment of Numbers to rank order categories. American Sociological Review, 35(2), pp. 515-524.

Labovitz, S. (1971) In defence of assigning numbers to ranks. American Sociological Review, 36(4), pp. 521-22.

Lalrindiki, M. & Gorman, B. (2016) Proximity and Inter-regional Innovation Systems: A look into Institutional Proximity. Conference: RSA Annual Conference, Graz. Available from: (PDF) Proximity and Inter-regional Innovation Systems: A look into Institutional Proximity (researchgate.net) [Accessed 31th August 2021].

Laurence, T. (2021) How Venture Capitalists Can Power The Fourth Industrial Revolution. Forbes. Available from: How Venture Capitalists Can Power The Fourth Industrial Revolution (forbes.com) [Accessed 25th June 2021].

Lerner, J. & Nanda, R. (2020) Venture Capital‘s Role in Financing Innovation: What We Know and How Much We Still Need to Learn. Journal of Economic Perspectives, American Economic Association, vol. 34(3), pp. 237-261, Summer. Available from: 20-131_fc73af76-3719-4b5f-abfc-1084df90747d.pdf (hbs.edu) [Accessed 27th August 2021].

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. (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.

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.

Leydesdorff, L. (2005) The Triple Helix Model and the Study of Knowledge-based Innovation Systems. International Journal of Contemporary Sociology, 42(1).

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.

Leydesdorff, L. & Van den Besselaar, P. (1994) Evolutionary Economics and Chaos Theory: New Directions in Technology Studies. (eds.) London and New York: Printer.

Li, Y. & Zahra, S.A. (2012) Formal institutions, culture, and venture capital activity: A crosscountry analysis. Journal of Business Venturing, 27(1), pp. 95-111.

Lincoln, J. & Ahmadjian, C. (2000) Shukko (Employee Transfers) and Tacit Knowledge Exchange in Japanese Supply Networks: The Electronics Industry Case. Institute of Industrial Relations, UC Berkeley, Institute for Research on Labor and Employment, Working Paper Series. Available from: https://doi.org/10.5465/apbpp.2000.5535064 [Accessed 20th August 2021].

Lundvall, B. (1985) Product Innovation and User-Producer 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 (ed.) London: Printer.

Lundvall, B.Å. (2007) National innovation systems - Analytical concept and development tool. Industry and Innovation, Vol. 14 No. 1, pp. 95–119.

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.

Luthra, S., Kumar, A., Zavadskas, E., Mangla, S. & Garza-Reyes, J.A. (2019) Industry 4.0 as enabler of sustainability diffusion in supply chain: analysis of influential strength of drivers in emerging economy. International Journal of Production Research, pp. 1-18. Available from: https://derby.openrepository.

com/bitstream/handle/10545/624165/IJPR.pdf?sequence=1&isAllowed=n [Accessed 25th May 2021].

Malerba, F. (2002) Sectoral systems of innovation and production, Research Policy, Vol. 31, pp. 247–264.

Malerba, F. & Nelson, R.R. (2013) Economic development as a learning process: variation across sectoral systems. Cheltenham: Edward Elgar.

Malerba, F. & Adams, P. (2019) Sectoral Systems of Innovation Sectoral Systems of Innovation Do Sectoral Differences Matter ?, No. November, pp. 1–24.

Martin, B.R. & Etzkowitz, H. (2000) The Origin and Evolution of the University Species. SPRU Electronic Working Paper Series, Paper 59.

MEITY (2012) National Policy on Information Technology. Government of India. Available from: www.meity.gov.in/writereaddata/files/National_20IT_20Policyt_20.pdf [Accessed 20th May 2021].

MHRD (2020) National Education Policy. Government of India. Available from: NEP_Final_English_0.pdf (education.gov.in) [Accessed 12 August 2021]

Miglani, S. (2019) The Growth of the Indian Automobile Industry: Analysis of the Roles of Government Policy and Other Enabling Factors. In: K.-C. Liu, U. S. Racherla (eds.) Innovation, Economic and Intellectual Property in India and China. Singapore: Springer, pp. 439-463.

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

Ministry of Commerce (2019) Draft National Logistics Policy. New Delhi. Available from: https://commerce.gov.in/writereaddata/UploadedFile/MOC_636850457336854610_Notification-Draft-05022019.pdf[Accessed 20th May 2020].

Ministry of Law and Justice (2019) The Motor Vehicles (Amendment) Act, 2019. New Delhi. Available from: http://egazette.nic.in/WriteReadData/2019/210413.pdf [Accessed 20th May 2020].

Ministry of Heavy Industries & Public Enterprises (2018) National Auto Policy (Draft Version 2). New Delhi. Available from: https://MHI.nic.in/writereaddata/UploadFile/National%20Automotive%20Policy%20Draft%20v2.pdf [Accessed 12th May 2020].

Ministry of Heavy Industries & Public Enterprises (2019) Fame India Scheme. Available from: https://pib.gov.in/PressReleasePage.aspx?PRID=1577880 [Accessed 13th May 2020].

Ministry of Heavy Industries & Public Enterprises (2019) Sanction for 5595 electric buses under FAME Phase – II. [press release] 08th August. Available from: https://pib.gov.in/Pressreleaseshare.aspx?PRID=1581525 [Accessed 14th May 2020].

Ministry of Housing and Urban Affairs (2019) Handbook of Urban Statistics. New Delhi. Available from http://mohua.gov.in/pdf/5c80e2225a124Handbook%20of%20Urban%20Statistics%202019.pdf [Accessed 16th May 2020].

Ministry of Urban Development (2014) National Urban Transport Policy, 2014. New Delhi. Available from: https://www.urbantransportnews.com/wp-content/uploads/2018/08/National_Urban_Transport_Policy_2014.pdf [Accessed 18th May 2020].

Ministry of Petroleum and Natural Gas (2018) National Policy on Biofuel 2018. New Delhi. Available from: http://petroleum.nic.in/sites/default/files/biofuels.pdf [Accessed 20th May 2020].

Mishra, S. (2022) Putting EV at forefront, Indian auto inc proposes USD 13 bn investment in 2021. ET Auto. Available from: ETAuto Original: Putting EV at forefront, Indian auto inc proposes USD 13 bn investment in 2021, Auto News, ET Auto (indiatimes.com) [Accessed 15th January 2022].

Mohnen, P., & Lars-Hendrik, R. (2001) Complementarities in Innovation Policy. CEPR Discussion Paper 2712. C.E.P.R. Discussion Papers. Available from: https://ideas.repec.org/p/cpr/ceprdp/2712.html [Accessed 3rd May 2021].

Moulaert, F. & Sekia, F. (2003) Territorial Innovation Models: A Critical Survey, Regional Studies, 37 (3), pp. 289-302, Available from: 10.1080/0034340032000065442 [Accessed 20th June 2021].

Mowery, D. C. (2009) Plus ca change: Industrial R&D in the “third industrial revolution”. Industrial and Corporate Change, 18(1), pp. 1-50.

Muffo, J.M., Sinclair, A., & Robson, V. (2003) A comparison of web versus paper alumni surveys. Paper presented at the Annual Forum of the Association for Institutional Research, Tampa, U.S.A. May 17-21.

Mukherjee, A. & Chawla, A. (2018) India as an Innovation Economy: The Role of IP and ICT. Available from: https://icrier.org/pdf/ICRIER-EBTC_White_paper_IP-ICT.pdf [Accessed 20th May 2020].

Mukherjee, S. (2017) Government to fund up to 60 per cent R&D cost for e-vehicles. The Economic Times. 11th January. Available from: Government to fund up to 60 per cent R&D cost for e-vehicles - The Economic Times (indiatimes.com) [Accessed 19th May 2020].

Nair, J. (2021) India's Struggle with Public Procurement Regulations. IndiaCorpLaw. Available from: India's Struggle with Public Procurement Regulations - IndiaCorpLaw [Accessed 8th October 2021]

Nakwa, K., Zawdie, G., & 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 Behavioural Sciences, Volume 52, p. 52-61, ISSN 1877-0428. Available from: https://doi.org/10.1016/j.sbspro.2012.09.441 [Accessed 25th August 2021].

Narasimhan, T. E. (2021) Automobile industry in India going through structural slowdown: SIAM. Business Standard. 29 January. Available from: Automobile industry in India going through structural slowdown: SIAM | Business Standard News (business-standard.com) [Accessed 25th August 2021).

National Automotive Testing and R&D Project (2018) Annual report 2017-18. Available from: http://natrip.in/download/Annual_Report_17-18.pdf [Accessed 20th May 2020).

National Skill Development Corporation (2017) Automotive Skills Development Council. Available from: https://www.nsdcindia.org/nos-listing/4 [Accessed 18th May 2020].

National Automotive Board (2020) FAME India Scheme Phase II. Home Page/About FAME II/Brief. Available from: https://fame2.heavyindustries.gov.in/content/english/13_1_brief.aspx [Accessed 13th May 2020].

National Automotive Board (2020) FAME India Scheme Phase II. Home Page/FAME – II Depository. Available from: https://fame2.heavyindustry.gov.in/content/english/32_1_FAMEDepository.aspx [Accessed 14th May 2020].

National Automotive Testing and R&D Project (2018) Annual Report 2107-18. New Delhi.

National Automotive Testing and R&D Project (2018) NATRIP Architecture. Available from: http://www.natrip.in/download/Natrip_architecture.pdf [Accessed 20th May 2020].

National Science Board (2018) Science & Engineering Indicators. Arlington, VA. Available from: https://www.nsf.gov/statistics/2018/nsb20181/assets/nsb20181.pdf [Accessed 29th May 2020].

Nauwelaers, C. (2009) Policy Mixes for R&D in Europe. European Commission – Directorate-General for Research. Available from: http://www.eurosfaire.prd.fr/7pc/doc/1249471847_policy_mixes_rd_ue_2009.pdf [Accessed 3rd May 2021].

Negro, S. O., Suurs, R. A. A. & 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), p. 57-77.

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.

Nelson, R. R., and Winter, S. G. (1982) An Evolutionary Theory of Economic Change, Cambridge, Mass: Harvard 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. & Harrison, N. (2019) Leveraging customer knowledge to enhance process innovation: moderating effects from market dynamics. Business Process Management Journal, 25(2), 307-322. Available from: https://doi.org/10.1108/BPMJ-03-2017-0076 [Accessed June 10th 2021].

NITI Aayog (2018) National Strategy for Artificial Intelligence. New Delhi. Available from: https://niti.gov.in/sites/default/files/2019-01/NationalStrategy-for-AI-Discussion-Paper.pdf [Accessed 28th May 2020].

OECD (1997) National Innovation Systems: Background Report. DSTI/STP/TIP(97)2, Paris. Available from: 2101733.pdf (oecd.org) [Accessed 20th May 2021].

OECD (2009) Overcoming Barriers to Administrative Simplification Strategies guidance for policy makers. Available from: https://www.oecd.org/regreform/42112628.pdf [Accessed 30th August 2021].

OECD (2011) Policy Framework for Investment User's Toolkit. Available from: https://www.oecd.org/investment/toolkit/policyareas/

publicgovernance/41890394.pdf [Accessed 30th August 2021].
OECD (2019) Productivity in Public Procurement. Available from: productivity-public-procurement.pdf (oecd.org) [Accessed 8th October 2021].
Okada, A., and Siddharthan, N. (2008) Automobile Clusters in India: Evidence from Chennai and the National Capital Region. In The Flowchart Approach to IndustrialCluster Policy. Edited by A. Kuchiki and M. Tsuji. London: Palgrave Macmillan, pp. 109–44.
Olcott, G. and Oliver, N. (2014) Social Capital, Sense-Making and Recovery from Disaster: Japanese Companies and the March 2011 Earthquake. California Management Review, vol. 56, no. 2, pp. 5-22. Available from: https://doi.org/10.1525/cmr.2014.56.2.5 [Accessed 10th June 2021].
Olsen, S.B. (2009) Choosing between internet and mail survey modes for choice experiment surveys considering non-market goods. Environmental and Resource Economics, 44 (4), pp. 591–610.
Oyelaran-Oyeyinka, B. (2005) Partnerships for Building Science and Technology Capacity in Africa. In: Africa-Canada-UK Exploration: Building Science and Technology Capacity with African Partners. 30 January - 1 February, London, UK.
Padilla-Pérez, R., and Yannick G. (2014) Science, Technology and Innovation Policies in Small and Developing Economies: The Case of Central America. Research Policy 43 (4): 749–59. Available from: https://doi.org/10.1016/j.respol.2013.10.011 [Accessed 20th June 2021].
Paisabazaar (2020) GST on cars in India. 19th April. Available from https://www.paisabazaar.com/tax/gst-on-cars/ [Accessed 20th May 2020].
Patra, G. (2021) The autonomous and electric vehicle future: What it will take for India to be ready. Financial Express. Available from:
The autonomous and electric vehicle future: What it will take for India to be ready - The Financial Express.. [Accessed 25th August 2021].
Paunov, C., and Rollo, V. (2016) Has the Internet Fostered Inclusive Innovation in the Developing World? World Development, 78, 587–609.
Perez, C. (1983) Structural change and assimilation of new technologies in the economic and social systems. Futures, 15(5), pp. 357-75.
Perkman, M., & Walsh, K., (2007) University-industry relationships and open innovation: towards a research agenda. International Journal of Management Review, 9 (4).
Pierrakis, Y., Saridakis, G. The role of venture capitalists in the regional innovation ecosystem: a comparison of networking patterns between private and publicly backed venture capital funds. J Technol Transf 44, 850–873 (2019). https://doi.org/10.1007/s10961-017-9622-8
Porter, M. (1990) The Competitive Advantage of Nations. Free Press, New York.
Pradhan, J. P., Singh, N., 2009. Outward FDI and Knowledge Flows: A Study of the Indian Automotive Sector, Institutions and Economies (formerly known as International Journal of Institutions and Economies), Faculty of Economics and Administration, University of Malaya, vol. 1(1), pages 156-187, June. Available at: View of Outward FDI and Knowledge Flows: A Study of the Indian Automotive Sector (um.edu.my) [Accessed on 26th August 2021]
Press Information Bureau (PIB) (2019) FAME India Scheme. Available at: FAME India Scheme (pib.gov.in). [Accessed on 9 October 2021]
Press Information Bureau (PIB) 2021, Government Notifies PLI Scheme for Automobile & Auto components. Available at:https://pib.gov.in/PressReleasePage.aspx?PRID=1757651#:~:text=PLI Scheme for auto sector,over Rs 2.3 lakh crore&text=The PLI Scheme for Automobile,2021. [Accessed on 21st October 2021]
PriceWaterHouseCoopers, 2017. Five trends transforming the Automotive Industry. Available at: ‹https://www.pwc.com/hu/hu/kiadvanyok/assets/pdf/five_trends_transforming_the_automotive_industry.pdf› [Accessed on 25th May 2020].
Priya, S. (2020) Once the darling of venture capitalists, how will automotive startups fare in corona driven economy? Economic Times. 14th June 2020. Available at: automotive startup funding: ETAuto Exclusive: Once the darling of venture capitalists, how will automotive startups fare in corona driven economy?, Auto News, ET Auto (indiatimes.com)) [Accessed on 7th October 2021]
PTI (2013) Budget 2013 impact: SIAM wants roll-back of extra tax on SUVs. The Economic Times, [online] (Last updated: 1st March, 2013, 06.06 PM IST). Available at: https://economictimes.indiatimes.com/budget-2013-impact-siam-wants-roll-back-of-extra-tax-on-suvs/articleshow/18750248.cms?from=mdr [Accessed on 25th May 2020].
PTI (2018) Government mandates preference to

India-made vehicles in public procurement. The Economic Times. 9th December 2018. Available at: Government mandates preference to India-made vehicles in public procurement - The Economic Times (indiatimes.com) [Accessed 8th October 2021]
PTI (2020) Lockdown impact: Automotive industry suffered Rs 2,300 crore loss per day, says par panel. The Economic Times. 15th December 2020. Available at: Lockdown impact: Automotive industry suffered Rs 2,300 crore loss per day, says par panel - The Economic Times (indiatimes.com) [Accessed 9th October 2021]
PTI (2021) Higher subsidy under FAME II to be key in adoption of EVs, say makers. Business Standard. 12 June 2021. Available at: Higher subsidy under FAME II to be key in adoption of EVs, say makers | Business Standard News (business-standard.com) [Accessed 10th October 2021]
Ranga, M., and Etzkowitz, H. (2013). Triple Helix systems: An analytical framework for innovation policy and practice in the Knowledge Society. Industry & Higher Education, 27(3): 237–262
Rao, R. (2019) Why automotive start-ups appeal to venture capitalists. Business Today. Available at: BT Buzz: Why automotive start-ups appeal to venture capitalists - BusinessToday [Accessed 18th January 2022].
Rao, S. V. R. (2021) Impact of COVID-19: A study of selected sectors. Management Matters. Volume 18. Issue 01. Available at: Management-Matters-April-2021.pdf (liba.edu). [Accessed 6th October 2021]
Raveendran, R., (2022) Top 10 Automobile Companies in India 2022. Top 10 Automobile Companies in India 2022 - IndianCompanies.in
Ray and Miglani (2016a) Innovation (and upgrading) in the automobile industry: the case of India, ICRIER Working Paper No. 320.
Ray and Miglani (2016b) A comparison of automobile industries in India and China, Ideas for India.
Ray, S. and S. Miglani, 2018. Global Value Chains and the Missing Links: Cases from Indian Industry. London and New York: Routledge.
Raziano, D.B., Jayadevappa, R., Valenzula, D., Weiner, M. & Lavizzo-Mourey, R., (2001). Email Versus Conventional Postal Mail Survey of Geriatric Chiefs. The Gerontologist 41(6), pp. 799-804
Ray, S. and S. Miglani (2020) India's GVC integration: An analysis of upgrading efforts and facilitation of lead firms, ICRIER Working Paper No. 386.
Reiljan, J., Paltser, I. (2015) The Role of Innovation Policy in National Innovation System: the Case of Estonia. – TRAMES, 19(69/64), No 3, pp 249-273. Available at: Microsoft Word - Reiljan.doc (kirj.ee) [Accessed on 30th August 2021].
Reischauer, G., 2018. Industry 4.0 as policy-driven discourse to institutionalise innovation systems in manufacturing. Technol. Forecast. Soc. Change 132, 26–33. https://doi.org/10.1016/J.TECHFORE.2018.02.012.
Renshaw, P. & Holland, D. (2013). Secondments - A Missed Opportunity?. Centre for Progressive Leadership. Available at: (PDF) Secondments - A Missed Opportunity? (researchgate.net) [Accessed 30th October 2021]
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.
Rummel, R.J., (1970). Applied Factor Analysis. Evanston: Northwestern University Press.
Sagar, A. D., & Chandra, P. 2004. Technological change in the Indian passenger car industry. BCSIA Discussion Paper 2004–05. Energy Technology Innovation Project, Kennedy School of Government, Harvard University.
Sakakibara, M. (1997). Heterogeneity of Firm Capabilities and Cooperative Research and Development: An Empirical Examination of Motives. Strategic Management Journal, 18, 143–164. http://www.jstor.org/stable/3088214
Samarth Udyog Bharat 4.0. CEFC Projects (Smart Manufacturing Demo and Development Cell at CMTI) [online] Available at ‹https://www.samarthudyog-i40.in/project› [Accessed on 18th May 2020].
Santiago, F., and Jose, M. N. (2014) Tiempos de Respuestas de La Dinámica Económica Asociados a La Inversión En Ciencia, Tecnología e Innovación En México. México: Foro Consultivo Científico y Tecnológico.
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, 142–152.
Saxenian, A. (1994), Regional Advantage: Culture and

Competition in Silicon Valley and Route 128, Harvard University Press, Boston.

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

SEBI, 2012. Securities and Exchange Board of India (Alternative Investment Funds) Regulations.

https://www.sebi.gov.in/legal/regulations/nov-2021/securities-and-exchange-board-of-india-alternative-investment-funds-regulations-2012-last-amended-on-november-09-2021-_34621.html

Seip, M., C. Castaldi, M. J. Flikkema, and A. P. De Man. 2018. "The Timing of Trademark Application in Innovation Processes." Technovation 72: 34–45. doi:10.1016/j. Technovation.2018.02.001. The timing of trademark application in innovation processes - ScienceDirect

Shaik, M. (2021) VCs, govt policies give a boost to start-up ecosystem. Hindu Business Line. 20 September 2021. Available at: VCs, govt policies give a boost to start-up ecosystem - The Hindu BusinessLine [Accessed 7th October 2021]

Sheth, A., Krishnan, S. & Samyuktha, T. (2020) India Venture Capital Report 2020. Perspectives on the Funding and Start-up Ecosystem. Bain and Company. Available from: bain_report_india-venture-capital-report.pdf [Accessed 30th October 2021].

SIAM (2021) Members. Available from: Society of Indian Automobile Manufactures (siam.in) [Accessed 20th June 2021].

Siegel, D.S., Waldman, D. & Link, A. (2003) Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: An exploratory study. Research Policy, 32(1), 27-48.

Sirmon, D.G., Hitt, M.A. & Ireland, R.D. (2007) Managing Firm Resources in Dynamic Environments to Create Value: Looking inside the Black Box. Academy of Management Review, 32, 273-292. Available from: http://dx.doi.org/10.5465/AMR.2007.23466005 [Accessed 20th June 2021].

Slowinski, G., & Sagal, M.W. (2006) Allocating patent rights in collaborative research. Research Technology Management, 49(1), 51–53.

Steel, K., Thompson, H., & Wright, W. (2018) Opportunities for intra-university collaborations in the new research environment. Higher Education Research & Development. 38 (1), 1-15. Available from: 10.1080/07294360.2018.1549537 [Accessed 20th June 2021].

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

Sturgeon, T. & Van Biesebroeck, J. (2009) Crisis and protection in the automotive industry: a global value chain perspective. In: Cattaneo, O., Evenett, S.J. and Hoekman, B. (eds.) Effective Crisis Response and Openness: Implications for the Trading System, CEPR and World Bank.

Sturgeon, T. & Van Biesebroeck, J. (2011) Global value chains in the automotive industry: an enhanced role for developing countries? Int. J. Technological Learning, Innovation and Development, Vol. 4, Nos. 1/2/3.

Sturgeon, T., Van Biesebroeck, J. & Gereffi, G. (2008) Value chains, networks and clusters: reframing the global automotive industry. Journal of Economic Geography. 8 (3), May, 297–321. Available from: https://doi.org/10.1093/jeg/lbn007 [Accessed 20th January 2022].

Suneja, K. (2020) Exports incentive scheme MEIS inefficient, failed to deliver, to be wound up by year end. Available from: Exports incentive scheme MEIS inefficient, failed to deliver, to be wound up by year end - The Economic Times (indiatimes.com) [Accessed 10th October 2021]

Sutton, J. (2004) The Auto-Component Supply Chain in China and India - A Benchmark Study. Suntory and Toyota International Centres for Economics and Related Disciplines, LSE, STICERD - Economics of Industry Papers.

Tether, B., S. & Tajar, A. (2008) Beyond industry-university links: Sourcing knowledge for innovation from consultants, private research organisations and the public science-base. Research Policy, Elsevier, 37(6-7), 1079-1095.

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

Tosun, J. & Lang, A. (2013) Coordinating and Integrating Cross-Sectoral Policies: A Theoretical Approach. 7th ECPR General Conference. Bordeaux, France, 4 - 7 September. Available from: http://projects.mcrit.com/foresightlibrary/attachments/article/1244/cd28bc3f-5dd9-43ba-a6c9-61f11a5ff0b8.pdf [Accessed 24th May 2020].

UITP India (2017) Mohua Unveiled Urban Green Mobility Scheme 2017. Available from: https://india.uitp.org/

news/mohua-urban-green-mobility-scheme-2017 [Accessed 21st May 2020].

Van Biesebroeck, J. & Sturgeon, T. J. (2010) Effects of the 2008-09 Crisis on the Automotive Industry in Developing Countries: A Global Value Chain Perspective. In: Cattaneo, O. Gereffi, G., and Cornelia, S., (eds.) Global Value Chains in a Postcrisis World: A Development Perspective. World Bank, pp. 209-244. Available from: https://openknowledge.worldbank.org/handle/10986/2509 License: CC BY 3.0 IGO

Villena, V. (2019) The Missing Link? The Strategic Role of Procurement in Building Sustainable Supply Networks. Production and Operations Management. Available from: https://doi.org/10.1111/poms.12980 [Accessed 30th October 2021].

Voß, J. & Simons, A. (2014) Instrument constituencies and the supply side of policy innovation: the social life of emissions trading. Environmental Politics 23, 735-754.

Weber, K.M. & Truffer, B. (2017) Moving innovation systems research to the next level: towards an integrative agenda. Oxford Review of Economic Policy. 33 (1), 101–121.

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

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.

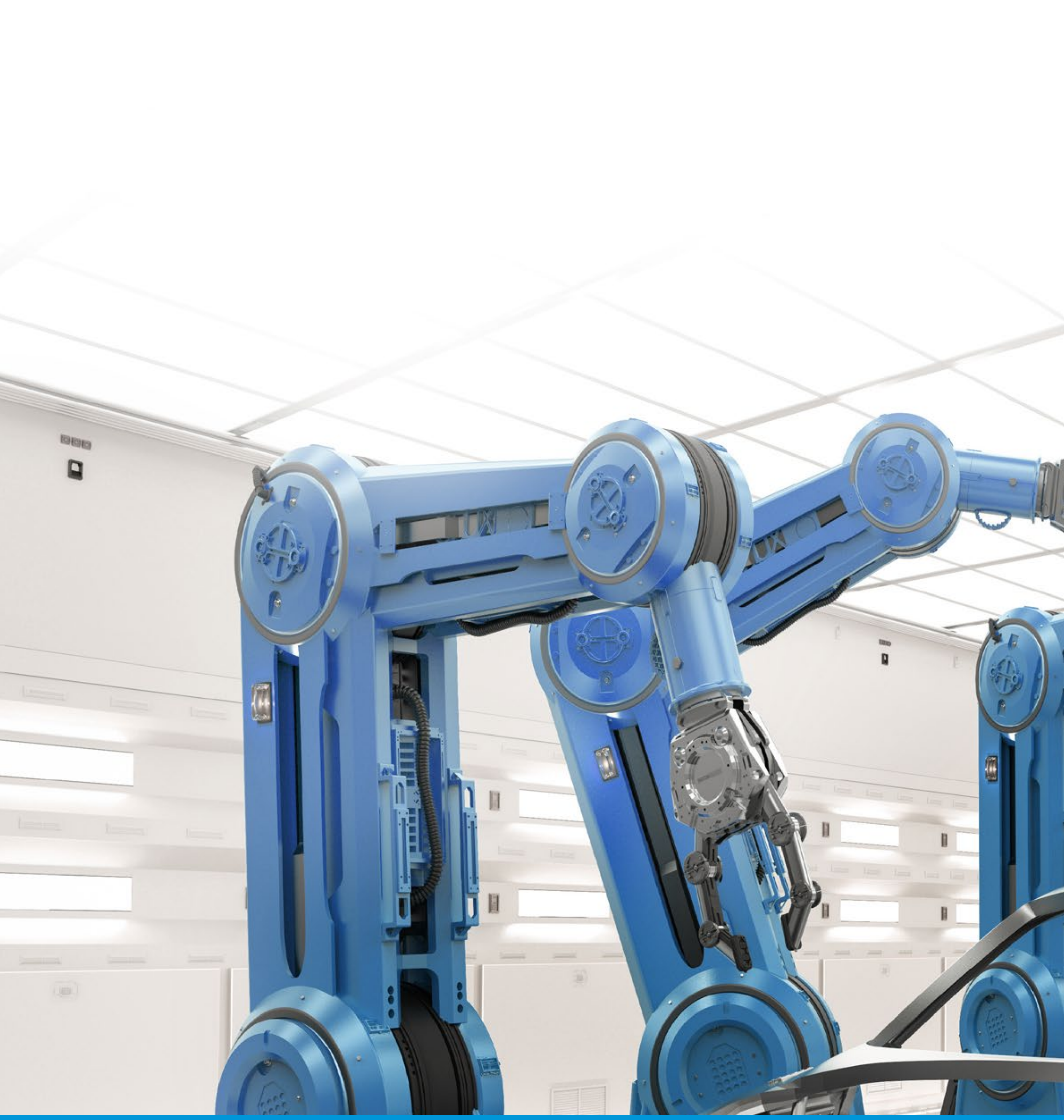
Winskel, M. & Moran, B. (2008) Innovation theory and low carbon innovation: Innovation processes and innovations systems. Edinburgh University.

WIPO (2021) Global Innovation Index 2021: Tracking Innovation through the COVID-19 Crisis. Geneva: World Intellectual Property Organization.

World Bank (2016) World Development Report: Digital Dividends. Available from: https://documents1.worldbank.org/curated/en/896971468194972881/pdf/102725-PUB-Replacement-PUBLIC.pdf [Accessed 15th June 2021].

WTO (2020) Trade set to plunge as COVID-19 pandemic upends global economy. Available from: https://www.wto.org/english/news_e/pres20_e/pr855_e.htm [Accessed 20th October 2021].

Zook, M. A. (2004) The knowledge brokers: Venture capitalists, tacit knowledge and regional development. International Journal of Urban and Regional Research, 28(3), 621–641.



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