EVALUATION OF INNOVATION EXCELLENCE INDICATORS

Report on
Public Funded
R&D Organisations

Volume I

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FOREWORD

PROFESSOR K VIJAYRAGHAVAN

Principal Scientific Adviser
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India has a vibrant Science, Technology, and Innovation (STI) ecosystem. It has consistently improved its rank in the global benchmark for innovation i.e., the Global Innovation Index (GII) in the last five years. It is noteworthy that as per GII 2021, India has attained the 3rd global ranking in terms of research publications and features within the top 50 innovative economies globally (at 46th rank).

India's public R&D organizations are increasingly being recognised as drivers of this ecosystem across diverse sectors covering agriculture, nutrition, communication, education, energy, health, water, transport, manufacturing, climate change, disaster management etc. In recent times they have come in the limelight as they have been complementing other government measures and the efforts of the private sector to combat the COVID-19 pandemic.

As India enters 75th year of Independence, it is time that we take stock, assess and evaluate our scientific prowess and achievements in the light of emerging national priorities and commitments towards AtmaNirbhar Bharat.

With this in view, the Prime Minister's office envisaged the need to undertake a detailed exercise for detailed and comparative assessment of all scientific institutions to infuse a spirit of competition among the institutions with a view to improve their outcomes. The framework for this exercise was developed by NITI Aayog after detailed consultations with stakeholders.

The framework of NITI Aayog has three main pillars: Socio-economic Impact, Science, Technology and Innovation (STI) Excellence, and Organisational Effectiveness. The pillar on 'Socio-economic Impact' captures the outcomes of a R&D lab's activities and its impact towards achieving national priorities. The pillar on 'Science, Technology and Innovation (STI) Excellence' captures the outputs of a R&D lab's activities. The pillar on 'Organisational Effectiveness' captures the effectiveness of a R&D lab in quality delivery of its mandate. There are a total of 11 sub-pillars in this framework and 62 indicators. Depending on the nature of R&D activities undertaken by the labs, the framework classified them into three categories – Basic, Applied or Services.

The Prime Minister's office entrusted the Office of Principal Scientific Adviser (O/o PSA) with the task of implementation of this framework developed by NITI Aayog by engaging a third-party agency for data collection and evaluation.

In pursuance to this request from PMO, the O/o PSA engaged the Confederation of Indian Industry (CII) and Centre for Technology, Innovation and Economic Research (CTIER) to implement the aforesaid framework and come out with a report on the performance of the publicly funded R&D labs and their contribution to the R&D Ecosystem.

This exercise was a challenging and complex task due to a wide diversity in the R&D performed by various organisations. It was difficult to compare and assess the value and performance of the R&D labs as each lab has its own niche and importance in the overall STI ecosystem. Being a first-time study, enormous efforts were made for getting a buy-in from the labs to participate and respond to the said questionnaires in a complete and coherent manner. Extensive handholding was done to familiarize the labs with the framework and the indicators.

The study has now been completed and CII has submitted the report titled "Evaluation of Innovation Excellence Indicators – A Report on Publicly Funded Organisations" to this office. This report is the first of its kind, and a very unique exercise to assess innovation indicators of centrally funded R&D organizations. By compiling data on R&D and innovation related inputs, systems, processes, outcomes and impact into exhaustive list of 62 indicators, this report provides an excellent overview of India's R&D and innovation landscape of public funded organizations. The report covers 193 labs out of the 606 R&D organizations which were the original scope of work of this exercise.

The report has three striking features. The first feature is that the report refrains from assigning any rank to a lab, as it would defeat the very purpose for which this exercise was conceived that is to make the lab more outcome oriented. On the contrary, the report has used the framework developed by NITI Aayog to compute scores to derive a spider chart which in turn reflects the performance of the labs under each category across the 11 sub pillars. The average pillar-wise performance for each category of labs has also been reported in the study. The second striking feature of this report relates to the way the data submitted by labs has been used in the computation of quartiles for relative performance. The third striking feature of this study is the individual lab sheets that provides the raw data submitted by labs scaled by either the budget of the lab or the scientific staff at the lab.

The key takeaway of this report is that it provides a tool to each R&D lab for self-assessment and course correction. The report is rich in data which can be used by each lab to assess/ rate its competencies on a set of parameters and compare its performance with other labs who are similarly placed. It can identify areas of strength and weaknesses so that the labs can take corrective action, improve its outcome and move up in the value chain. The mechanism is transparent and user friendly.

The report has brought forth, four sets of key recommendations that have been covered in detail in the subsequent chapters. The first set of recommendations relate to Strengthening engagement with the national STI ecosystem. These recommendations explore various ways in which a R&D lab can strengthen existing linkages with other stakeholders in the national STI ecosystem such as industry, higher education institutions (HEIs), start-ups and other R&D labs. Second set of recommendations are towards Strengthening organisational capabilities. These recommendations explore the various ways in which a R&D lab can improve its own capacity and capabilities towards better outputs and outcomes by optimizing human resources,

resource allocation and infrastructure. The third set of recommendations focus on Improving contribution towards societal benefits. These recommendations focus on the crucial role of scientific institutions and their activities towards the benefits of Indian Society. The fourth and the last set of recommendations focus on Increasing scientific and policy contribution to global development challenges. These set of recommendations explore improved national engagement on a global scale.

As an immediate step forward, this report recommends constitution of an Expert Committee for revaluating this framework and enhancing the value of this framework based on the feedback received from the participating labs. The revised framework would also be ensuring alignment with other emerging national priorities and could be a tool for second round of the survey which was recommended in the framework of NITI Aayog.
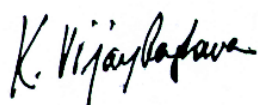
The report in its draft stage was circulated for comments to 23 stakeholder departments with a request to share it with all participating R&D labs under their respective administrative control. Comments were received from the departments/labs, examined and suitably incorporated in the final report. The final report is a rich compendium of data on performance and contribution of all the 193 participating labs. It shows future pathways for labs to strengthen their own capabilities, and help further R&D labs' contribution for societal benefit and increase their engagement with the wider world.

I would like to thank and extend my sincere appreciation to Shri. V.K. Saraswat, Member, NITI Aayog and to Prof. Goverdhan Mehta and his team for devising the framework on which this report is based. I also thank the members of the Working Group constituted by my office for their valuable insights, which have enriched this report.

I wish to place on record my sincere appreciation for the dedicated work done by my team consisting of Dr. Arabinda Mitra, former Scientific Secretary, O/o PSA, Shri. J.B. Mohapatra, former Senior Adviser, O/o PSA and present Chairman, CBDT, Shri. Suresh Kumar, former Scientist, O/o PSA, Shri. B.N. Satpathy, Senior Consultant, O/o PSA and Shri. Suneet Mohan, Consultant, O/o PSA for their valuable contribution to the formulation and finalisation of this Report.

I also acknowledge the support provided by the team from CII consisting of Shri. S. Raghupathy, Principal Adviser, Shri. Ashish Mohan, Head, Technology, Ms. Namita Bahl, Director, Technology, Ms. Divya Arya, Executive Officer, Technology, and by the team from CTIER consisting of Shri. Janak Nabar, CEO, Ms. Swati Joshi, Senior Research Associate, Ms. Dipti Singhania, Research Associate and Ms. Vaishnavi Dande, Research Associate, for completing this gigantic exercise.

In conclusion, I take this opportunity to express my sincere gratitude to PMO for giving my office the opportunity to come out with this pathbreaking report on public funded R&D institutions in the country. This will be a valuable document for all concerned.

February 2022
New Delhi
India

Professor K VijayRaghavan

PREFACE

DR ARABINDA MITRA

Former Scientific Secretary, O/o PSA
and Chairman of the Working Group
Evaluation of Innovation Excellence Indicators

Science, Technology and Innovation (STI) are the key drivers of economic growth and social empowerment. Research and Development (R&D) is central to build a vibrant STI ecosystem. India has a rich legacy of public funded R&D organizations, some of which even pre-dates our independence. These institutions are indeed home to new knowledge creation and veritable powerhouse to drive innovation economy, creating potential for countless collaboration between industry and academia. They account for utilizing a significant share of the R&D budget of the Government of India.

The Office of Principal Scientific Adviser (O/o PSA) at the behest of the Prime Minister's Office initiated an exercise for capturing and evaluating the innovation indicators of public funded R&D organizations so as to qualitatively and quantitatively comprehend and highlight the contribution made by these institutions. This exercise was based on the initial framework developed by NITI Aayog. The objective was to assess the absolute and relative strengths and weakness of these labs and provide the labs an opportunity to reassess their own mandate and re-evaluate their research output in alignment with contemporary national needs and missions.

The Confederation of Indian Industry (CII) and Centre for Technology, Innovation and Economic Research (CTIER), Pune were engaged as knowledge partners who enthusiastically and persistently undertook the two year long exercise, impeded due to the pandemic. A Working Group under my Chairmanship with representatives from key scientific departments of Government of India did periodically oversee the exercise to its final conclusion.

The making of this report, which is first of its kind, has been a dynamic and a learning process. A key aspect was to ensure timely and voluntary data collection required to develop the analytical framework based upon 62 identified parameters identified in consultation with the laboratories. Upon comprehending the value and usefulness of this empowering exercise, it was indeed heartening to receive a forthcoming response from the participating labs. The key attribute of the process was to introduce the labs to new indicators aimed at aligning the publicly funded research with outcome

oriented goals. Another notable aspect relates to scientific and researcher staffing which bring forth the data related to women researchers and young scientists, which is one of the most important parameters to ensure empowerment, equity, diversity and inclusion in our research institutions.

To conclude, this exercise has revealed that the publicly funded R&D organizations have defined but diversified priorities. The need however is to work with a shared purpose, in synergy with national goals and through seamless collaboration with the eco-system that can make their R&D outcome more impact oriented. In this direction, the exercise shall go a long way in fostering techno-innovation and R&D ecosystem, that can quantifiably contribute to the economic development, social inclusion and sustainability for achieving an all-encompassing, technology driven Atmanirbhar Bharat.

I would like to convey my gratitude to the members of the Working Group and to the Heads of the R&D labs who made this report a reality. I appreciate their active contribution and hope that a periodic updation of the report will serve as an enabler in strengthening the future research and innovation ecosystem of the country.

February 2022
New Delhi
India

Dr Arabinda Mitra

ACKNOWLEDGEMENTS

ABOUT THE REPORT

This report details the findings from the implementation of the framework established by NITI Aayog to assess the absolute and relative strengths and weaknesses of India's publicly funded R&D organisations. The labs being covered in this study are impacting the wider economy in a variety of ways. Their research and contribution not only have implications for the domestic economy, but also offer opportunities that can be of direct impact to the global community.

The purpose of this report is to capture innovation indicators and the research being undertaken by various public funded R&D organisations. The report also helps gauge performance of the labs with respect to their socio-economic contribution, STI excellence and organisational capabilities and practices. For the organisations themselves, the report provides an opportunity to identify areas of untapped potential and interventions to improve the labs' performance in the areas mentioned above. Lastly, the report makes several actionable policy recommendations that may be considered to improve the outputs and outcomes from these R&D organisations.

There is a wealth of information that emerges from the data captured in the study, and the public research ecosystem could use the framework developed to constructively complement and at the same time scale up some of their existing activities to benefit India's R&D ecosystem more widely.

This report is divided into two volumes. In Volume I, Section 1 offers the reader a broad overview of the study with details of the background, framework and methodology, while Section 2 captures the findings from the analysis of the data collected. In Volume II, Section 3 introduces the concept of individual lab sheets and contains the details of individual labs that participated in this study. Section 4 contains the Appendix. The appendix also includes a summary statement of the feedback received from the labs/ ministries/ departments and actions taken with respect to the feedback.

EXECUTIVE SUMMARY

Background

India's public R&D organisations have been playing a significant role in the overall innovation and R&D ecosystem. They impact the wider economy through their work in sectors such as healthcare, agriculture, energy and environment, transport and infrastructure, livestock and industries like food processing, textiles etc. They play an important role in addressing a number of societal and developmental challenges. In the coming years, as India seeks new models of innovation to drive its growth story, and as the prominence of these institutes is likely to increase, it becomes important to create a baseline of the current contributions made by these institutes. This will also help identify the various ways in which this contribution can be increased to better align with our country's needs and priorities.

The present report outlines and implements a framework that has been developed to evaluate the innovation excellence of public funded R&D organisations.

Objectives of the study are to:

A. Capture innovation indicators and the research being undertaken by various public funded R&D organisations.

B. Assess the performance of the labs with respect to their socio-economic contribution, STI excellence and organisational capabilities and practices.

C. Identify areas of untapped potential and interventions to improve the labs' performance in the identified areas.

D. Propose a roadmap for improvement of the outputs and outcomes from these R&D organisations.

Framework - Salient features

NITI Aayog, under the chairmanship of Dr. V K Saraswat, Member, NITI Aayog conducted several discussions with the stakeholders to prepare a framework to improve outcomes of public funded R&D organisations. The Task Force, chaired by Professor Goverdhan Mehta, in its report, noted that there is a wide diversity in the R&D performed by various organisations, and it is difficult to compare the value and performance of the R&D as each has its own niche

and importance in the overall STI ecosystem. Nevertheless, all public funded R&D institutes could be grouped into three categories (basic, applied and services) based on the type of R&D performed. Common attributes amongst these institutes were used to devise a sector-agnostic framework.

The framework has three main pillars - Socio-economic Impact, Science, Technology and Innovation (STI) Excellence, and Organisational Effectiveness. The pillar on 'Socio-economic Impact' captures the outcomes of a R&D lab's activities and its impact towards achieving national priorities. The pillar on 'Science, Technology and Innovation (STI) Excellence' captures the outputs of a R&D lab's activities. The pillar on 'Organisational Effectiveness' captures the effectiveness of a R&D lab in quality delivery of its mandate. There are a total of 11 sub-pillars in this framework and 62 indicators.

Scope of the Study

In March 2019, the Office of Principal Scientific Adviser (PSA) was entrusted by the Prime Minister's Office (PMO) to finalise and implement a functional framework developed by NITI Aayog to assess the absolute and relative strengths and weaknesses of India's public funded R&D institutions.

Accordingly, a pilot study was initiated by the Office of the PSA, targeting around 14 organisations. Based on the pilot results, subsequent revisions were made to the questionnaires to ensure ease of understanding, minimise the time and efforts of the respondents and ensure accuracy and consistency. A subsequent pilot was conducted with 7 labs to test the web platform and ease of online data submission by the R&D organisations.

All 606 R&D organisations listed in the Directory of R&D Institutions 2018 published by the Department of Science and Technology (DST) were invited to participate in the study. For the purpose of this report, the term 'R&D institutes/labs/organisations' is used as an all-encompassing term to include all those organisations, institutes, cooperative research associations and educational institutions that perform R&D and are identified in the Directory of R&D Institutions 2018 published by DST.

Data collection and validation

A total of 193 R&D labs were considered for this report. The participating labs were spread across the country and included labs from most major scientific agencies such as Council of Scientific and Industrial Research (CSIR), the Indian Council of Agricultural Research (ICAR), the Indian Council of Medical Research (ICMR), Department of Biotechnology (DBT), the Department of Science and Technology (DST) and other Central Government Ministries/ Departments.

Labs were given the option to classify themselves based on the R&D undertaken into one of three categories – Basic, Applied or Services. The organisations also had the option to classify themselves as a hybrid R&D lab i.e. one whose research coverage straddled more than one of the three research categories. Data was collected for three years, 2017-18, 2018-19 and 2019-20 through a specially designed online portal (www.indiascienceindicators.gov.in).

The raw data was validated using the structured templates and other supporting documents. Where possible, any inconsistencies due to minor errors were corrected for. In other cases,

queries were collated for individual labs and sent to respective labs for clarification. Four webinars were convened for final query resolution. Only the primary data submitted by labs was used for analysis after validation.

Data Quality

The collection of high-quality responses to the web-based questionnaire was facilitated through multiple measures. Templates were introduced to standardise the format in which supporting documents and data were collected from labs. Other measures included five orientation webinars for nodal officers, preparation of manuals to guide nodal officers in understanding the questionnaire and its requirements. Further, a systematic process of query resolution was instituted to address individual questions from laboratories during the process of filling the questionnaire. Additional assistance, where possible, was provided to laboratories based on their individual requirements. This was done through calls/ emails with the Nodal officers, for example facilitating collaborations with other labs to access publication related information on Scopus or Web of Science.

Key highlights

One of the key contributions of the report is the presentation of the individual lab sheet. One of the objectives of the NITI framework was to rank & rate the labs. However, the report does not assign any ranking or rating to the labs. Instead, the report presents individual lab sheets which provides the raw data submitted by the labs scaled by either the budget of the lab or the scientific staff at the lab. These sheets serve as a tool for labs to assess their own strengths and weaknesses and thereby help them improve performance and competitiveness.

   A. Capture innovation indicators and the research undertaken by public funded R&D organisations

   B. Assess the lab with respect to its socio-economic contribution, STI excellence and organisational capabilities

   C. Identify areas of untapped potential

A. Innovation indicators and the research being undertaken by public funded R&D organisations

Presenting such information by each indicator in the lab sheet shall provide forward guidance to the labs to identify opportunities that might become an area of focus depending on their mandate. Each lab sheet that focuses on the following three aspects:

Highlights of the individual lab sheet
○ The lab sheet displays performance of the lab, indicator-wise with respect to socio-economic contribution, STI excellence and organisational capabilities and practices.
○ A colour code is assigned depending upon the quartile to which the response belonged.
○ The responses of all 193 labs is taken into account when computing the quartiles for the indicators.
○ The lab sheet also contains information on the lab's mandate, location, thrust areas of research and type of R&D performed.

B. Assessment of labs with respect to their socio-economic contribution, STI excellence and organisational capabilities

The labs being covered in this study are impacting the wider economy in a variety of ways. The labs are a repository of knowledge and are playing an important role in addressing several societal and developmental challenges. Some of the areas of strength and innovation excellence by pillar are appended below:

Areas of Strength and Innovation Excellence by pillar

Socio-economic Impact

- The labs being covered in this study are impacting the wider economy in a variety of ways across sectors such as healthcare, agriculture, energy and environment, transport and infrastructure, livestock and industries like food processing, textiles etc.

- The technologies that are being transferred are largely to the domestic economy and therefore currently having a direct impact on the domestic economy.

- Around 1,97,000 individuals benefited from training programmes undertaken by various public funded institutions in 2019-20 and this number has increased over the period under consideration.

Science, Technology and Innovation (STI) Excellence

- At an aggregate level, there has been an increase in publication output from 15,788 in 2017-18 to 16,202 in 2019-20.

- Around 1513 new products and 1480 new services have been introduced over the three years.

- There were 666 technologies with TRL levels between 0-4 and 1192 technologies with TRL levels 5 and higher (targeting SDGs and national programmes) that were being developed in 2019-20.

Organisational Effectiveness

- High share of young researchers (i.e. researchers below the age of 40), the median value has remained around 64 percent

- The labs are adhering to several of the best practices outlined in the framework. Around 90 percent of the labs have provisions for differently abled facilities.

- 95 percent of labs have incentives in place to promote talent. 98 percent of labs have a structured career plan for their scientific staff.

C. Areas of untapped potential and related interventions

The areas of untapped potential have been identified to help labs enhance their outputs and widen impact. Some of them are provided below:

Areas of Untapped Potential by pillar

Socio-economic Impact

○ The labs are largely targeting SDG goal 1 'No poverty' and SDG goal 3 'Good health and well-being'. A wider segment of the SDGs can be targeted

○ While there is significant impact on domestic economy, there remains a scope for labs to enhance global presence and research collaborations thereby providing home grown solutions to global development challenges.

○ Currently, 35 labs out of 193 labs are providing incubation support to startups. Labs should be further encouraged to expand collaborations with industry and startups.

Science, Technology and Innovation (STI) Excellence

○ There is scope to increase the quality of their publication output. The current median level for percent of publications in top 10 percent journals is closer to 6 percent.

○ With just 37 percent of labs collaborating with industry in India and around 8 percent collaborating with industry overseas, there is a need to increase engagement with industry

○ While there was a significant amount earned by labs by way of consultancy fees, it appears that this is being driven by a small number of labs. Participating in collaborative research would increase the scope for greater extramural funding from non-government sources.

Organisational Effectiveness

○ While 40 percent of labs studied have a software system to track and manage their projects from conception to completion, there is a greater need for digitalization.

○ Around one third of the participating labs mentioned that they do not have national or international accreditation/certification, which needs to be scaled up

○ Labs would need to address increasing the share of women researchers in their scientific staff; the median value remains low at 30 percent in 2019-20.

D. Recommendations of the study

Based on the above findings, we propose a set of recommendations that shall lay down a roadmap for improving the outcomes from public funded R&D institutes. The recommendations are grouped into four main categories:

1. Strengthening engagement with the national STI ecosystem

2. Strengthening organisational capabilities

3. Improving contribution towards societal benefits

4. Increasing scientific and policy contribution to global development challenges

Strengthening engagement with the national STI ecosystem

These recommendations explore various ways in which a R&D lab can strengthen existing linkages with other stakeholders in the national STI ecosystem such as industry, higher education institutions (HEIs), startups and other R&D labs. All public R&D labs are a precious repository of accumulated knowledge and dissemination of knowledge from these labs to the wider ecosystem will have several far-reaching positive impacts.

Towards the aforesaid objectives, the recommendations are as follows:

-   Expand research collaborations with industry and increase engagement with startups

-   Explore the establishment of mechanisms based on proven international models of collaboration for translational research

-   Improve cross-linkages between labs and between labs and HEIs

Strengthening organisational capabilities

These recommendations explore the various ways in which a R&D lab can improve its own capacity and capabilities towards better outputs and outcomes by optimising human resources, resource allocation and infrastructure. These recommendations include:

-   Mandate certification and accreditation for lab procedures

-   Improve technology commercialisation and facilitate IPRs

-   Capacity building and ensuring more diversity and inclusion

Improving contribution towards societal benefits

These recommendations focus on the crucial role of scientific institutions and their activities towards the benefits of Indian society. The study findings establish that, all R&D labs are committed towards reaching out to the Indian society in general for improving the social dividends by their research products. These recommendations explore how the current contributions can be enhanced to tackle different challenges faced by Indian society ranging from poverty, malnutrition, access to water, healthcare and education improving equity for all. These include:

-   Align research and development with national needs and priorities

-   Improve access to scientific resources by educational institutions

-   Engage civil society in dissemination of knowledge and create a portal to improve engagement with students

Increasing scientific and policy contribution to global development challenges

India has been a partner of choice for many countries for the development of new scientific knowledge and collaborations. India can play a bigger role on the global stage and expand her growth ambitions through STI. A number of indigenously developed scientific solutions has the potential to tackle and mitigate global challenges like climate change, food security, green energy solutions, healthcare, etc.

These set of recommendations explore improved engagement on a global scale. These include:

- Increase international project collaborations
- Enhance extramural funding to boost the STI ecosystem
- Explore collaborations for technology promotion

Way forward

There are several ways in which this framework may be used by the policymakers, some of the potential ways are enlisted below:

Potential uses of the study

- Showcase the contribution of public funded R&D labs to India's innovation ecosystem
- Contribute to national and international statistics on public R&D in India
- Show future pathways for R&D labs to strengthen their own capabilities
- Further R&D labs' contribution for societal benefit and increase their engagement with the wider world

As this is the first time a complex exercise like this has been undertaken, there are several learnings that have emerged that can be used for the benefit of future exercises. Provided below are the recommendations that may help strengthen the framework as well as the processes of data collection and validation.

Formation of expert committee to re-evaluate the framework

The formation of an expert committee is a vital step towards enhancing the value of this framework and ensuring alignment with national priorities. Recommendations include:

- Clearly defining the eligibility criteria and what constitutes a public R&D lab
- Revisit weights of the pillars and sub-pillars and applicability of certain indicators to better reflect the role of public R&D labs
- Assistance from domain experts to evaluate qualitative responses

Institutionalizing the process of data collection and validation

Line ministries/departments can play an important role in supporting the data collection process in a more systematic and centralised manner. Recommendations include:

- Support of line ministries/departments in data collection
- Aligning the data reported in the annual reports with the 62 indicators
- Embedding the data templates in the portal for effective validation

Participating ministries/departments have an important role to play in the refinement of the framework going forward. Every effort should be made to familiarise the participating ministries/departments about the immense potential of such a framework. Ongoing, iterative and collaborative efforts among all the stakeholders would be necessary to ensure the success of future rounds of this study, as well as broaden the scope of such studies across the wider research and innovation ecosystem.

ACRONYMS

AYUSH	Ministry of Ayush (Ayurveda, Yoga, Unani, Siddha, Sowa-Rigpa and Homoeopathy)
CSIR	Council of Scientific & Industrial Research
DAE	Department of Atomic Energy
DBT	Department of Biotechnology
DHI	Department of Heavy Industry
DoP	Department of Pharmaceuticals
DoS	Department of Space
DoT	Department of Telecom
DPIIT	Department for Promotion of Industry and Internal Trade
DRDO	Defence Research and Development Organisation
DST	Department of Science and Technology
EDI	Equity, Diversity and Inclusion
FDI	Foreign Direct Investment
HEI	Higher Education Institutes
ICAR	Indian Council of Agricultural Research
ICMR	Indian Council of Medical Research
IISER	Indian Institutes of Science Education and Research
IPR	Intellectual Property Rights
MeitY	Ministry of Electronics and Information Technology
MoA	Ministry of Agriculture
MoC&F	Ministry of Chemicals and Fertilizers
MoEFCC	Ministry of Environment, Forest and Climate Change
MoES	Ministry of Earth Sciences
MoFPI	Ministry of Food Processing Industries
MoHUA	Ministry of Housing and Urban Affairs
MoM	Ministry of Mines
MoP	Ministry of Power
MoRD	Ministry of Rural Development

MoRTH	Ministry of Road Transport and Highways
MSME	Ministry of Micro, Small & Medium Enterprises
PMO	Prime Minister's Office
PSA	Principal Scientific Adviser
R&D	Research and Development
S&T	Science and Technology
SDGs	Sustainable Development Goals
SME	Small Medium Enterprise
STI	Science,Technology and Innovation
STIP	Science Technology and Innovation Policy
TRL	Technology Readiness Level

SECTION 1

OVERVIEW OF THE STUDY

INTRODUCTION

1.1 Background

India's public R&D institutions have been playing a significant role in the overall innovation and R&D ecosystem. They impact the wider economy through their work in sectors such as healthcare, agriculture, energy and environment, transport and infrastructure, livestock and industries like food processing, textiles etc. They play an important role in addressing a number of societal and developmental challenges. In the coming years, as India seeks new models of innovation to drive its growth story, it becomes important to create a baseline of the current contributions made by public funded R&D labs and identify the various ways in which this contribution can be increased to better align with our country's needs and priorities. In view of this, and as per the directions of PMO, a framework for innovation excellence indicators of the public funded R&D institutions has been developed.

Multiple deliberations had been held under the Chairmanship of Dr. V K Saraswat, Hon'ble Member, NITI Aayog for preparing a framework for innovation excellence assessment of various R&D labs working under different Ministries/ Departments such as Department of Science and Technology (DST), Department of Biotechnology (DBT), Council of Scientific & Industrial Research (CSIR), Defence Research & Development Organisation (DRDO), Ministry of Electronics and Information Technology (MeitY), Ministry of Earth Sciences, Department of Space, Department of Atomic Energy, Indian Council of Agriculture Research (ICAR), and Indian Council of Medical Research (ICMR).

The initial framework for this study was subsequently developed by a Task Force constituted by NITI Aayog under the leadership of Prof. Goverdhan Mehta, Chairman, National Accreditation Board of Education & Training, Quality Council of India & Chairman of Task Force Quality Council of India with members drawn from leading scientific institutions and Confederation of Indian Industry (CII) to devise the framework. Copy of the Task Force composition is provided in the Appendix.

The Task Force noted that there is tremendous diversity in the nature of R&D carried out by various publicly funded R&D organisations under different departments. It proposed that despite the diversity, R&D organisations can be grouped into three categories - Basic, Applied, and Services and a sector agnostic framework that looks at the common attributes of these

categories was put forth. The Task Force prepared a list of 30 R&D labs and characterised them into 3 groups (about 10 labs in each- Basic, Applied and Services) for the purpose of deliberations and inclusive views of each kind of category. The definitions of the three categories of labs can be found in Table 1.1 below.

Table 1.1 Definitions of Research Categories – Basic, Applied, Services

Category	Definition
Basic R&D	Experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.
Applied R&D	Original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective.
Services R&D	Systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, directed to producing new products or processes or to improving existing products or processes.

While the pillars are common to all three categories of organisations, the weights attached to each of these pillars vary by category.

After multiple meetings with Secretaries of various Ministries/ Departments, Directors of 30 R&D labs representing 10 labs each of 3 categories, other stakeholders and the Task force prepared a framework which was finalised after the consent of Secretaries and Task force members. The framework used in this report builds on this initial framework.

In March 2019, the Office of Principal Scientific Adviser (PSA) was entrusted by the Prime Minister's Office (PMO) to finalised and implement a functional framework to assess the absolute and relative strengths and weaknesses of India's public funded R&D institutions. CII was engaged as the Knowledge Partner by the Office of PSA for implementation of the framework.

The framework for the 'Evaluation of Innovation Excellence Indicators of Centrally Funded R&D Organisations from the NITI Aayog consultations was then finalised following consultations with a Working Group led by the Scientific Secretary, Office of the PSA, and comprising relevant stakeholders as well as nodal officers appointed by various ministries.

The next section provides an overview of the framework used to evaluate the labs at an aggregate level as well as explains how the framework has been adapted to assess the performance of Basic, Applied and Services R&D labs.

1.2 Framework - Salient Features

The framework has three main pillars - Socio-economic Impact, Science, Technology and Innovation (STI) Excellence, and Organisational Effectiveness. Each pillar has a number of sub-pillars and indicators as we shall see below. Figure 1.1 provides an overview of the framework. The pillars and sub pillars with comparisons across the three categories of labs i.e. Basic, Applied and Services, are further explored later in the section.

The framework has three main pillars – Socio-economic Impact, Science, Technology and Innovation (STI) Excellence, and Organisational Effectiveness. The three main pillars cover a total of 11 sub-pillars and 62 evaluation parameters.

Figure 1.1 Overview of the framework

Pillars	Outcomes ⤺ Socio-economic Impact	Outputs ⤺ Science, Technology and Innovation Excellence	Inputs ⤺ Organisational Effectiveness
Sub-pillars	Contribution to India's SDGs and National Programmes Employment Generation and Human Resources Development	Scholarly Research Output and Quality Development and Innovation Output and Quality Commercialisation of Technologies Revenue Generation and Collaborative Research	Mandate Alignment Resource Management Governance Equity, Diversity and Inclusion (EDI) Internal Capacity

The 'Socio-economic Impact' pillar captures the outcomes of a R&D organisation's activities and its impact towards achieving national priorities. The sub-pillar 'Contribution to India's SDGs and National Programmes' captures the contribution of a R&D organisation through questions on the number of technologies targeted towards SDGs and National Programmes, main beneficiaries of the organisation's programmes. The sub-pillar 'Employment Generation and Human Resources Development' captures outcomes through questions on increase in staff, number of PhDs and Master's generated, startups incubated, employment generated through startups etc.

The 'Science, Technology and Innovation (STI) Excellence' pillar captures the outputs of a R&D institutions activities through four sub-pillars viz., 'Scholarly Research Output and Quality', 'Development and Innovation Output and Quality', 'Commercialisation of Technologies and Revenue Generation and Collaborative Research'. The questions under this pillar capture data on publications and citations, IPR filed and granted, technologies transferred, new product and services developed and collaborative research undertaken with other national and international R&D organisations and industry.

The 'Organisational Effectiveness' pillar captures the effectiveness of a R&D organisation in quality delivery of its mandate through five sub-pillars viz., 'Mandate Alignment', 'Resource Management', 'Governance', 'Equity, Diversity and Inclusion (EDI)' and 'Internal Capacity'. The effectiveness of a R&D institution is captured through questions on mandate alignment, share of scientists, share of budget spent on R&D, promotion of equity, diversity and inclusion, facilities being differently-abled friendly, structured career development programmes, etc.

The pillar weights assigned to the framework for each category of lab varies. In the case of Basic Labs, the pillar weight for STI Excellence is significantly more than the weight attached to the other two pillars. In the case of Applied Labs and Services Labs, equal weightage has been given to the 'Socio-economic Impact' pillar and the 'STI Excellence' pillar and is higher than the weight attached to the 'Organisational Effectiveness' pillar. There are further differences in the relative importance of sub-pillars and indicators across the three categories of labs.

Table 1.2 Relative importance of sub pillars across the three categories

Pillars	Sub pillars	Basic R&D	Applied R&D	Services R&D
Pillar 1: Socio-economic Impact	Sub-pillar 1: Contribution to SDGs and national programmes	🟧	🟥	🟥
	Sub-pillar 2: Employment generation and human resource development	🟧	🟧	🟧
Pillar 2: Science, technology and innovation excellence	Sub-pillar 3: Scholarly research, development output and quality	🟥	🟧	🟧
	Sub-pillar 4: Development and innovation output and quality	🟥	🟧	🟧
	Sub-pillar 5: commercialisation of technologies and revenue generation	🟧	🟧	🟧
	Sub-pillar 6: Collaborative research	🟨	🟧	🟧
Pillar 3: Organisational effectiveness	Sub-pillar 7: Mandate alignment	🟧	🟨	🟨
	Sub-pillar 8: Resource management	🟨	🟨	🟨
	Sub-pillar 9: Governance	🟨	🟨	🟨
	Sub-pillar 10: Equity, diversity, and inclusion	🟨	🟨	🟨
	Sub-pillar 11: Internal capacity building	🟨	🟨	🟨

🟥 Higher-range   🟧 Mid-range   🟨 Lower-range

Looking at Table 1.2, for basic R&D labs, sub-pillars 1 and 2 are equally weighted. With respect to the overall framework, the weight assigned to these two sub-pillars ranks below that of sub-pillar 3 and 4.

In the case of the applied and services labs, the distribution of weights between the sub-pillars is the same for both the categories. Sub-pillar 1 has a significantly higher weight than sub-pillar 2, and is in fact the highest weighted sub-pillar in the framework for both applied and services labs. The difference between the applied and services labs would be seen at the indicator level.

Table 1.3 Socio-economic Impact pillar

Indicators under Pillar 1: Socio-economic Impact	
Sub pillar 1: Contribution to SDGs and national programmes	Technologies targeted towards SDGs and National Programmes
	Projects Executed
	Beneficiaries of lab's programmes
	Contribution to national policy improvement**
	Outreach activities
	People attending skill development, entrepreneurship and innovation trainings
	National and International programmes organised (S&T symposia, conferences, etc.)
Sub pillar 2: Employment generation and human resource development	Increase in existing employee base through technologies transferred
	Increase in the number of staff engaged in R&D
	Startups incubated
	Startups exited
	New hires by the current incubatees
	Consultancies undertaken for startups***
	PhDs, Masters and Graduate degrees awarded*
	PhDs examined by one or more foreign assessors*
	Interns trained*
	Trainings imparted**
	Skill development programmes conducted**
	Permanent scientists deputed to provide training**

*Only for Basic and Applied R&D questionnaires **Only for Services R&D questionnaire ***Only for Basic R&D questionnaire

The indicators captured under sub-pillars 1 and 2 are shown in Table 1.3.

Table 1.4 Science, technology and innovation excellence pillar

Indicators under Pillar 2: Science, technology and innovation excellence	
Sub pillar 3: Scholarly research, development output and quality	National and International Awards and Fellowships
	Publications in quality peer reviewed journals
	Commissioned technology development/design/project reports prepared
	Citations*
	Percent of publications in top 10% journals*#
	Technology documents prepared**
	National and International recognitions received by the lab**
	Reports leading to designs and products**
Sub pillar 4: Development and innovation output and quality	IPR filed
	IPR granted
	IPR licensed out
	National and International policies, regulations and standards contributed to
	Technologies transferred domestically and internationally
	New services and products introduced
Sub pillar 5: commercialisation of technologies and revenue generation	Earnings from government and non-government sources
	Extramural funding received from government and non-government sources
Sub pillar 6: Collaborative research	National and International collaborative projects with industry
	National and International collaborative projects with academic/ research organisation
	National and International collaborations measured by publications with academic organisation/industry
	Scientists attached to industry/academic organisation under an exchange program*

*Only for Basic and Applied R&D questionnaires **Only for Services R&D questionnaire #Based on available indicator in Web of Science

Within the STI excellence pillar, for basic R&D labs, the sub-pillar 3 has been assigned the highest weight followed by sub-pillar 4 and then sub-pillar 6. In the overall framework for basic R&D labs, these three sub-pillars also have a higher weight than the other sub-pillars, with a lot of emphasis especially being placed on sub-pillar 3. Sub-pillar 5 is among the lower weighted sub-pillars in the overall basic R&D framework.

For the applied and services labs, within the STI excellence pillar, sub-pillars 3, 4 and 5 are equally weighted and have a higher weight compared to sub-pillar 6. The weights of the sub-pillars across applied and services are the same within the STI excellence pillar, and the

difference between these two categories of labs would be seen at the indicator level. In the context of the overall framework, sub-pillars 3, 4 and 5, while among the higher weighted sub-pillars, have a relatively lower weight compared to sub-pillar 1. Sub-pillar 6 in the case of applied labs as well as services labs is among the lowest weighted sub-pillars in the overall framework.

Table 1.5 Organisational effectiveness pillar

Indicators under Pillar 3: Organisational effectiveness	
Sub pillar 7: Mandate alignment	Extent to which R&D being carried out is in line with lab's vision, mission and objectives
	New research fields/innovations/services introduced
	Ability to adapt and change orientation in response to local challenges and global scientific advancement
Sub pillar 8: Resource management	Percentage of permanent scientists and contractual researchers
	Percentage of organisation's budget spent on R&D and S&T
Sub pillar 9: Governance	Effective communication of the lab's objective and strategy to its staff?
	Requisite SOP/guidelines for lab's processes
	Initiatives in place to promote intra-organisational collaborations
	Software system to track and manage research projects
	Ethics guidelines and policies
	Sexual harassment mitigation cell with requisite policies and procedures
	Public grievance redressal cell
	National/international accreditation/certification for lab procedures
	Transparent recruitment guidelines and processes
	Outside researchers who undertook research at the lab
	Website details and scheduled update & maintenance
Sub pillar 10: Equity, diversity, and inclusion	EDI (Equity, Diversity and Inclusion) cell
	Percentage of young scientists and researchers to the total scientific and research staff
	Percentage of women scientists and researchers to the total scientific and research staff
	Differently-abled friendly facilities at the lab
Sub pillar 11: Internal capacity building	Percentage of budget spent on training & skill up-gradation of staff
	Structured career progression plan for non-scientific and scientific staff
	Percentage of scientists who have undergone a career development programme
	Incentives in place to promote talent

In the Organisational Effectiveness pillar, the distribution of weights across the sub-pillars is the same across the three categories of labs. The sub-pillars 7 and 9 have the highest weighting in this pillar followed by sub-pillar 8. The sub-pillars 10 and 11 have the lowest weighting within the framework.

1.3 Implementation of the Framework

Prior to the launch of the larger study in August 2020, a pilot study was initiated by the Office of the PSA in March 2019, targeting around 14 organisations. The organisations in the pilot study were required to categorise themselves as either Basic, Applied, Services or Hybrid labs (i.e any two or all three categories of labs) and submit data, in response to paper-based questionnaires, along with the necessary supporting documents. The responses received from around 14 R&D organisations during the pilot study were evaluated according to their respective categorisations and subsequent revisions were made to the questionnaires.

> **Organisations were given the option to classify themselves based on the R&D undertaken into one of three categories – Basic, Applied or Services. The organisations also had the option to classify themselves as a hybrid R&D organisation i.e. one whose research coverage straddled more than one of the three research categories mentioned.**

A second pilot was run with 7 labs to test the web platform and the revised questionnaires and templates. An orientation webinar was conducted with the labs before the labs started filling in the data to explain the process of data collection. All queries of these labs were addressed and feedback incorporated where possible.

The larger study was launched in August 2020 targeting 606 institutions listed in the DST Directory of R&D Institutions 2018. A total of 193 lab responses were finally considered for the purpose of analysis. The 193 labs were largely from the major scientific agencies that include ICAR, CSIR, ICMR, DBT and DST as well as other central government ministries.

Chapter 2

SCOPE OF THE STUDY - R&D LABS AND THEIR CHARACTERISTICS

The sample in this study consists of 193 institutions that are part of the 606 R&D institutions listed in the Directory of R&D Institutions 2018 published by the Department of Science and Technology (DST). All 606 R&D institutions were invited to participate in the study.

Of these 193 institutions, there were 6 institutions from the Ministry of AYUSH that had a total of 49 peripheral institutions belonging to them. These peripheral institutions were accounted for in the responses of the 6 institutions. Furthermore, these 49 peripheral institutions had originally been listed as separate R&D institutions in the DST directory. Thus of the 606 R&D institutions in the DST directory, the data that has been analysed covers 232 institutions listed in the DST directory.

In response to the request for participation, there were 41 institutions that had immediately requested for exemption from the exercise citing they were ineligible to participate. There were 30 institutions from the Department of Atomic Energy (DAE), Department of Space (DoS) and the Defence Research and Development Organisation (DRDO) that had initially submitted their responses to the survey, but subsequently requested for an exemption from the current exercise. Separately, there had been a further 8 institutions belonging to major scientific agencies and other central government ministries that had also submitted their responses. However, these 8 institutions were not considered during the evaluation exercise as these were new labs or were in the process of being established or had responded saying they did not perform any R&D.

Figure 2.1 shows the distribution of the 193 participating labs across ministries. A majority of the participating laboratories were from the Indian Council of Agricultural Research (ICAR), followed by the Council of Scientific and Industrial Research (CSIR), Indian Council of Medical Research (ICMR), Department of Biotechnology (DBT) and Department of Science and Technology (DST).

Figure 2.1 Ministry/Department wise breakdown of 193 labs in the final sample

23
Others

5
MoES

5
MoEFCC

6
Ministry of Ayush*

4
MeiTY

17
ICMR

34
CSIR

13
DBT

13
DST

73
ICAR
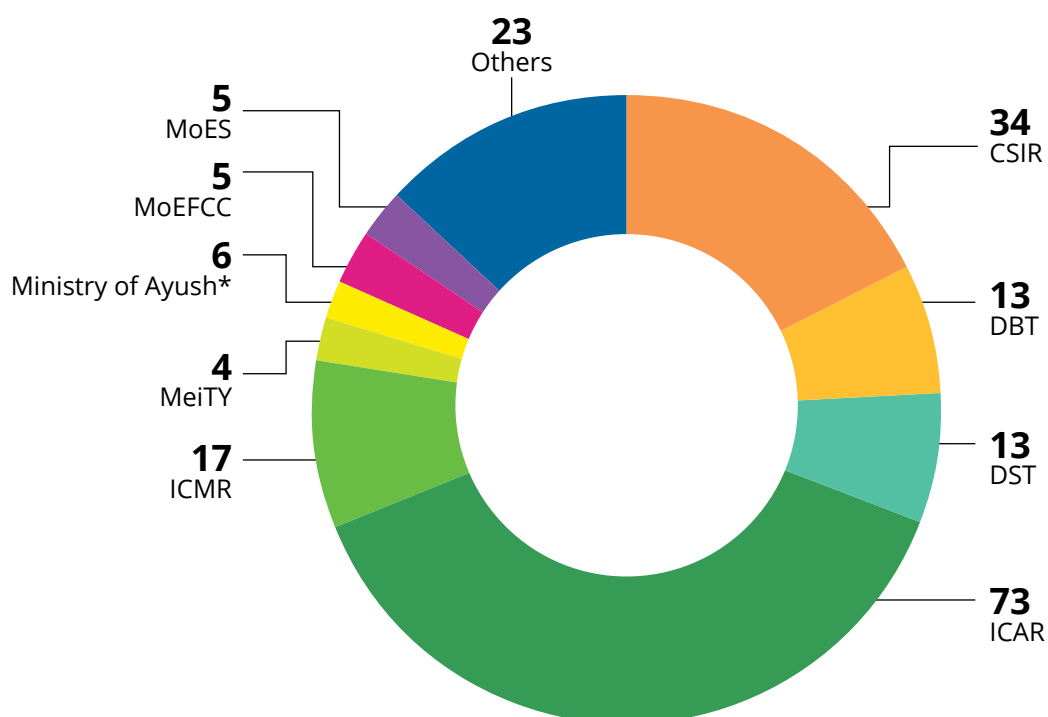
The six labs from Ministry of Ayush cover 49 peripheral institutions

2.1 Geographical Spread of Participating Organisations

The participating organisations were spread across the country, with the Northern region having the largest concentration of labs, mostly driven by the significant number of labs present in states such as Delhi and Uttar Pradesh. The Eastern region had the lowest share of the 193 participating labs at around 20 percent. The majority of labs in the Western region were from the state of Maharashtra. The state wise distribution of these organisations is presented in Figure 2.2. There was representation across mostly all states and union territories in the country.
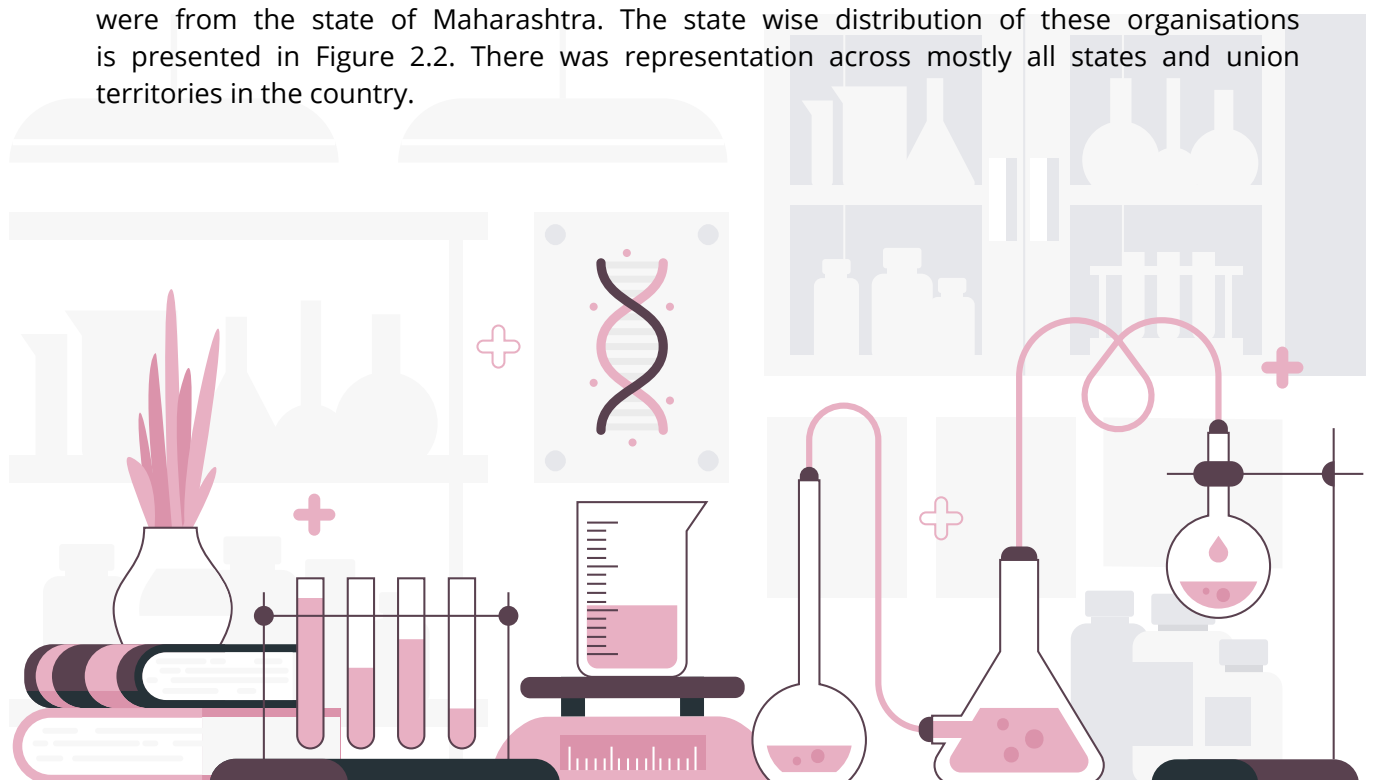
Figure 2.2 Geographical Distribution of Participating Organisations
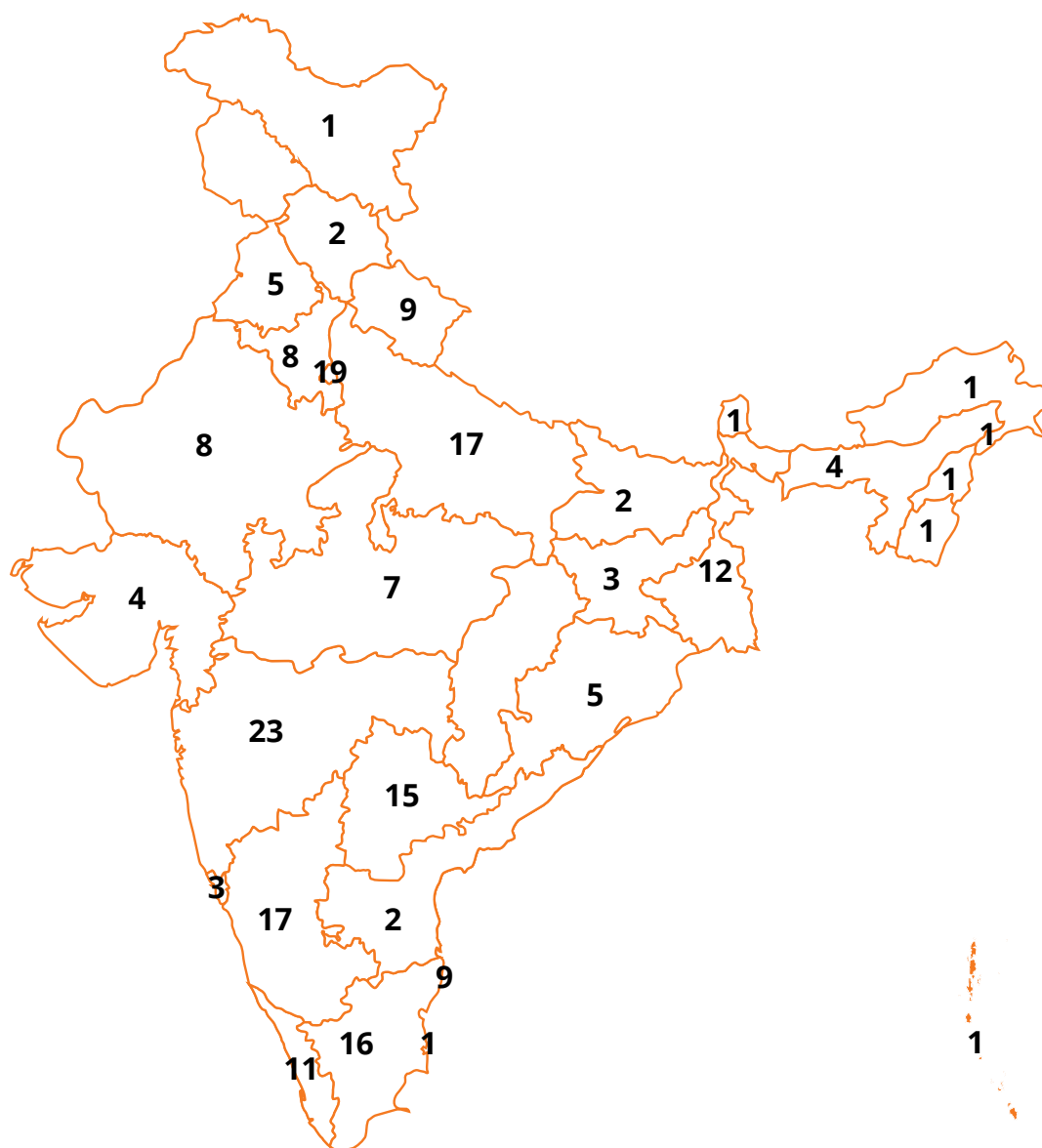
2.2 Scientific Staff and Budget distribution of the Participating Organisations

The total scientific staff at these labs ranged from around 28,000 in 2017-18 to around 31,000 in 2019-20. The scientific staff comprise both permanent scientists at these labs and the contractual researchers hired for projects. Figure 2.3 shows the distribution of scientific staff across the various participating ministries and departments. A majority of the scientific staff are hired under the CSIR department. CSIR and ICAR alone account for around 51 percent of the total scientific staff at these labs. 'Other institutions' which majorly comprise Cooperative Research Associations and Educational Institutions represent around 11 percent of total scientific staff.

Figure 2.3 Distribution of the total scientific staff across the various Ministries/Departments
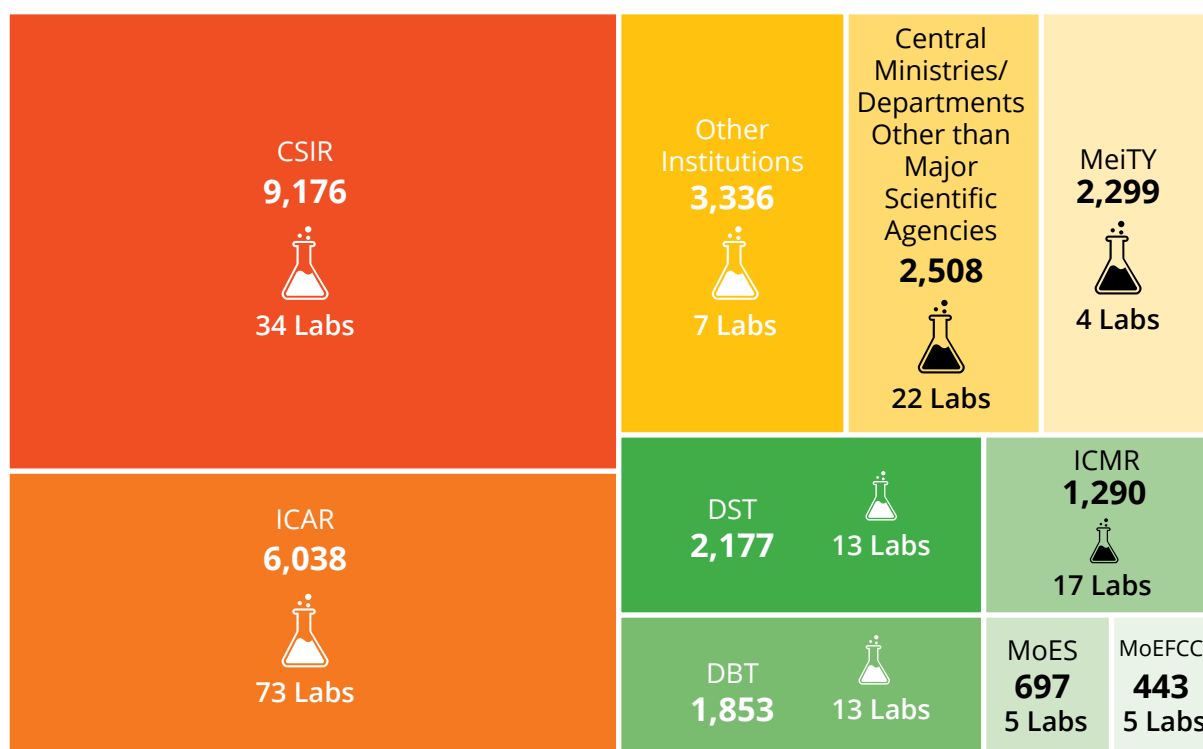
CSIR 9,176 — 34 Labs	Other Institutions 3,336 — 7 Labs	Central Ministries/ Departments Other than Major Scientific Agencies 2,508 — 22 Labs	MeiTY 2,299 — 4 Labs
ICAR 6,038 — 73 Labs	DST 2,177 — 13 Labs	ICMR 1,290 — 17 Labs	
	DBT 1,853 — 13 Labs	MoES 697 5 Labs	MoEFCC 443 5 Labs

Note: Other institutions include Cooperative Research Associations and Educational Institutions

*The six labs from Ministry of Ayush cover 49 peripheral institutions

The 193 participating organisations reported an average budget of Rs. 12,914 Cr per year for the period under consideration. CSIR represents the largest share of the total budget followed by the Indian Council of Agricultural Research (ICAR). However, based on the number of labs participating from each department or ministry, the average budget per lab was highest for MoES. The average budget for CSIR labs was Rs. 108 Cr and for ICAR labs was around Rs. 43 Cr.

Figure 2.4 Distribution of the total budget across the various Ministries/Departments
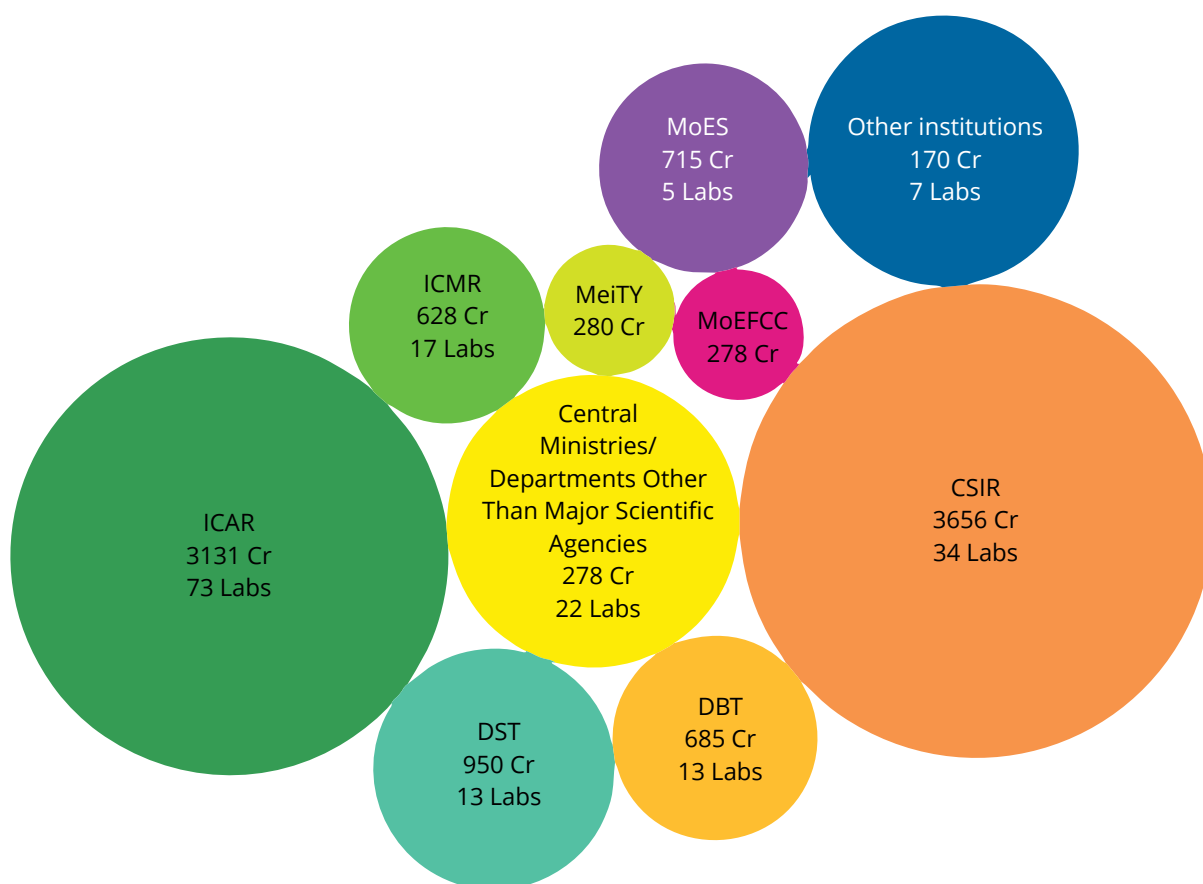
Note: Other institutions include Cooperative Research Associations and Educational Institutions

*The six labs from Ministry of Ayush cover 49 peripheral institutions

2.3 Breakdown by the 'Type of R&D performed'

The 193 labs had to self select their category of R&D performed i.e. Basic, Applied, Services, and were also eligible to respond to the questionnaires of more than one category of lab in case they were hybrid labs.

As seen in Figure 2.5, of the 193 labs, there were 45 labs that considered themselves as performing pure basic R&D, 21 labs that were performing both basic R&D and applied R&D, 4 labs that were performing basic R&D and services R&D, 72 labs that were performing pure applied R&D, 15 labs that were performing applied R&D and services R&D, 16 labs that were performing pure services R&D and 20 labs that were performing basic, applied and services R&D.

A majority of labs were performing only Applied R&D and accounted for a budget of approximately Rs. 4472 Cr. This was followed by 45 labs which were performing only Basic R&D and accounted for a budget of approximately Rs. 3582 Cr.

Figure 2.5 Distribution of 193 labs by the 'type of R&D performed' along with their budget
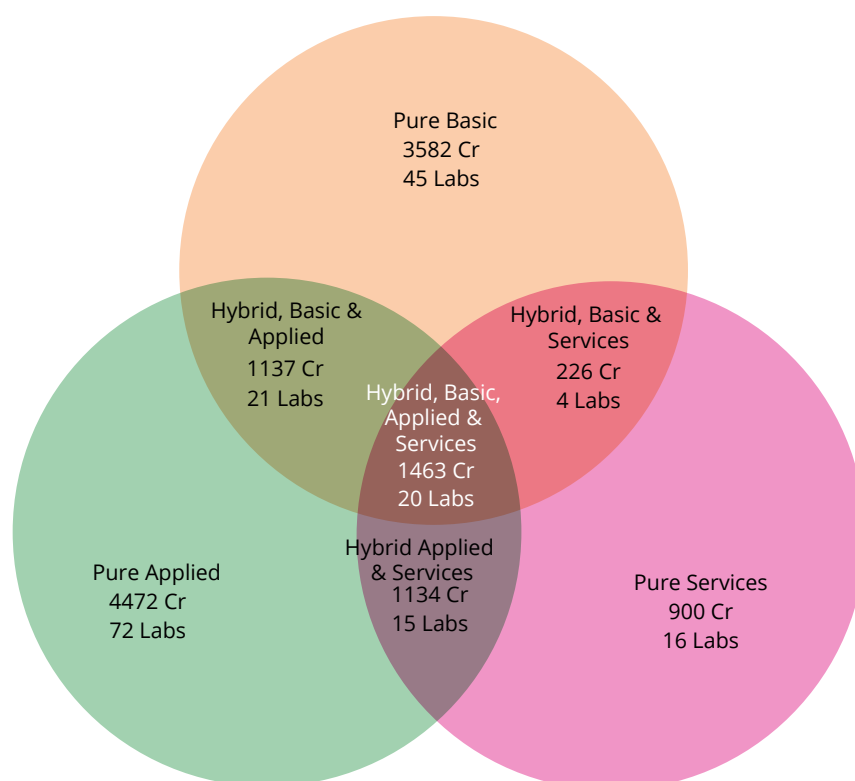
Figure 2.6 captures the distribution of the labs across various ministries and departments by their type of R&D performed

Figure 2.6 Breakdown by department and 'type of R&D performed'
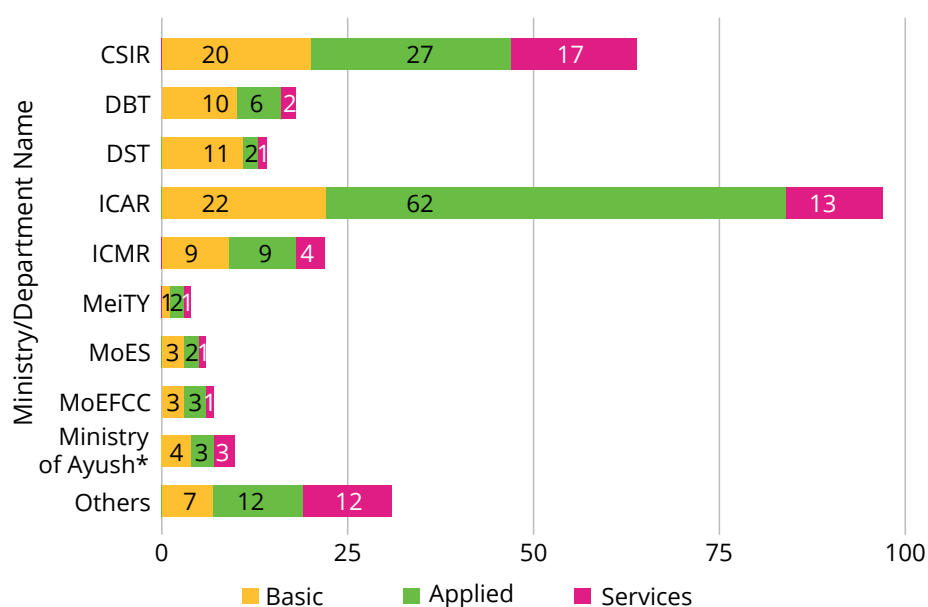
The six labs from Ministry of Ayush cover 49 peripheral institutions*

DATA AND INDICATORS

In this chapter, we describe the questionnaire, the processes of data collection and data validation.

3.1 Survey Instrument - Innovation Excellence Indicators

There were three questionnaires developed from the framework: one each for Basic, Applied and Services R&D organisations. Based on the findings from the pilots and the feedback received from the Working Group, the questionnaires were finalised to ensure ease of understanding and to minimise the time and effort required of the respondents.

The questionnaire was made more user-friendly through language modification, splitting of questions, addition of FAQs, examples to questions, while retaining the essence of the NITI framework. In addition, templates were introduced to facilitate data collection and validation across labs and for receiving supporting data in a standardised format. Several of the FAQs and some templates were inspired by responses of some of the organisations themselves submitted during the pilot. The examples provided as well as data tables that had been submitted as supporting information for certain responses were incorporated in the questionnaires.

Each questionnaire had a total of 62 questions along with a cover page and supporting documents. Some questions had sub-questions. Relevant explanatory notes, instructions and FAQs were provided for each question. There were three main types of questions as shown in the table below. In addition, there was one question that required a response on a likert scale. The number of questions by types for each of the three questionnaires can be found in Table 3.2.

Table 3.1 Types of questions

Type of Questions	Description
Numeric	Response required in percentage terms or absolute numbers
Binary	Yes/No response required
Qualitative	Subjective in nature and required descriptive responses

Table 3.2 Number of questions by type, in the questionnaires for Basic, Applied Services labs

Type of Question	Basic R&D Labs Questionnaire (No. of Questions)	Applied R&D Labs Questionnaire (No. of Questions)	Services R&D Labs Questionnaire(No. of Questions)
Numeric	41	41	41
Binary	17	17	16
Likert	1	1	1
Qualitative	3	3*	4*

The questionnaire for Applied Labs also has two sub-questions while the questionnaire for Services Labs also has one sub-question that requires a qualitative response.

The 'cover page' included basic details about the organisation, their location, correspondence addresses and details of the appointed nodal officers. The cover page document also contained information pertaining to the organisation's budget and staff strength for the reporting period.

Supporting documents included three types: templates in downloadable format (in excel), screenshots and policy documents. A total of 18 templates were created such that they covered close to half the questions. In some cases, a template was designed on particular themes to cover multiple questions. This included questions that required mandatory supporting documents as well as questions that did not have this requirement. For example, the template on workforce required responses to questions like increase in the number of permanent scientists, increase in the number of contractual researchers for projects, percentage of young scientists and researchers, percentage of women scientists and researchers. This was done to facilitate the collection of lab-level data in a standard format across labs for validating the responses entered by labs. All templates were required to be vetted by the respective Directors of participating labs.

3.2 Data Collection

The data collection for this study took place from August 2020 to November 2020.

All data was collected online. The participating organisations went through a registration process on the website. They were also sent a copy of the questionnaires along with the introductory email. Data was collected for three years, 2017-18, 2018-19 and 2019-20. The collection of high-quality responses to the web-based questionnaire was facilitated through multiple measures to assist organisations in understanding and responding to the questionnaires. These measures included orientation webinars for nodal officers, the preparation of manuals to guide nodal officers in understanding the questionnaire and its requirements. Further, a systematic process of query resolution was instituted to address individual questions from laboratories during the process of filling the questionnaire.

3.2.1 Development and Online Testing of Web Platform

A website was developed to facilitate online data submission by the R&D organisations.

Figure 3.1 Screenshot of the platform

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1. All response boxes were coded to receive specific input. For example, numeric questions did not accept alphabets, thus reducing the possibility for error in the responses.

2. A dashboard was incorporated for the user to keep track of answered and incomplete or unanswered questions.

3. Templates for supporting documents, in downloadable excel format, were included under the corresponding questions. An option to upload the filled in templates, under the corresponding question, was clearly visible to the respondent.

4. All questions and uploading of supporting documents was made mandatory. Pop-up reminder windows were included for the benefit of the respondent.

5. Prior to final submission, the labs encountered a cover page that requested general information about the organisation, including data on the overall budget and scientific staff for three financial years. The labs had the option to fill in data for more than one type of questionnaire, without having to register multiple times. Hybrid labs, however, were required to fill in each questionnaire separately.

Development of Supplementary Material

A detailed user manual was prepared to provide details on how best to approach the exercise and the do's and don'ts when responding to the questionnaire. It included background information, list of instructions for ease of response, a glossary and other useful information. In addition, a new section for 'Frequently Asked Questions' was created. This included the most frequent queries from respondents and was frequently updated throughout the duration of the study. Over 130 FAQs were listed on the web portal. The 'Manual for Participating Organisations' and 'Frequently Asked Questions' were made accessible on the web portal.

Lastly, supplementary material in the form of a presentation was prepared for the orientation workshop and was emailed on request.

3.2.2 Process of Data Collection

The process of data collection is outlined below. It included nomination of the nodal officer, orientation workshops, query resolution and online submission.

Nomination of Nodal Officers

The first step of data collection was a directive sent to all laboratories to nominate Nodal officers for data aggregation. The role of the nodal officers was to coordinate the exercise and be the designated central point of contact for all future correspondence/ engagements. The nodal officer was also responsible for presenting and getting data duly vetted by the Director of the organisation before final submission.

Orientation Workshops

A series of 5 webinars was conducted between August to October 2020, to orient nodal officers to the questionnaires, supporting documents, and templates. At each webinar close to 150-200 Nodal officers were taken through the entire process of participating in the exercise.

This was done through a comprehensive presentation which was used to guide each webinar and take nodal officers through the structure of the instrument, the nature of the questions, the supporting documents required, and the format for filling up templates that were designed to support data aggregation. Nodal officers were also encouraged to put forth their queries during the orientation webinars and their queries and responses to the queries were recorded.

Figure 3.2 Process of Data Collection

Data Collection Process

Nomination of the Nodal Officers	Orientation Webinars	Query Resolution	Online Submission
• Labs were requested to nominate nodal officers to coordinate the exercise • Designated central point of contact for all future correspondence/ engagements	• Introduction to web instrument, supporting documents, and templates	• Prompt clarifications to all queries received from labs were provided via email and calls. • List of FAQs continuously updated on web platform	• Attachment of templates • Filling in of cover page and survey instrument • Survey instrument submission

Query Resolution

A system for prompt resolution of queries from individual labs facilitated the timely collection of high-quality data. Close to 200 queries from different laboratories were answered through emails and calls. The queries thus responded to were finally compiled in a comprehensive list of Frequently Asked Questions (FAQs) and uploaded to the website for further assistance. This list of FAQs was continuously updated and was made available on the web platform.

Online Submission

There were 231 laboratories that submitted their responses via the web platform. For the purpose of analysis, the final number of labs considered were 193 as explained in Chapter 2.

3.3 Data Validation

A total of 273 questionnaire responses (including for hybrid labs) were received - these included 90 responses for Basic labs, 128 responses for Applied labs and 55 responses for Services labs. The data collected was for FY2018, FY2019 and FY2020, and thus a total of 819 responses needed to be validated. Each questionnaire had around 62 questions. The raw data downloaded from the platform was validated using the data entered in the templates and other supporting documents. Where possible, any inconsistencies due to minor errors were corrected for. In other cases, queries were collated for individual labs and sent to the labs for clarification. The processes of validation, comprising checking, correcting and query resolution have been described below.

Figure 3.3 Process of Data Validation for One R&D Organisation

Data Validation Process for One R&D Organisation

Data Validation from Templates

Data Validation for non-template questions

Data Validation for Cover Page

Check for Hybrid Lab data

Preparation of Clarification sheets

Follow up calls/ emails for clarification

Webinars for final query resolution

Data cleaning and data entry of validated data
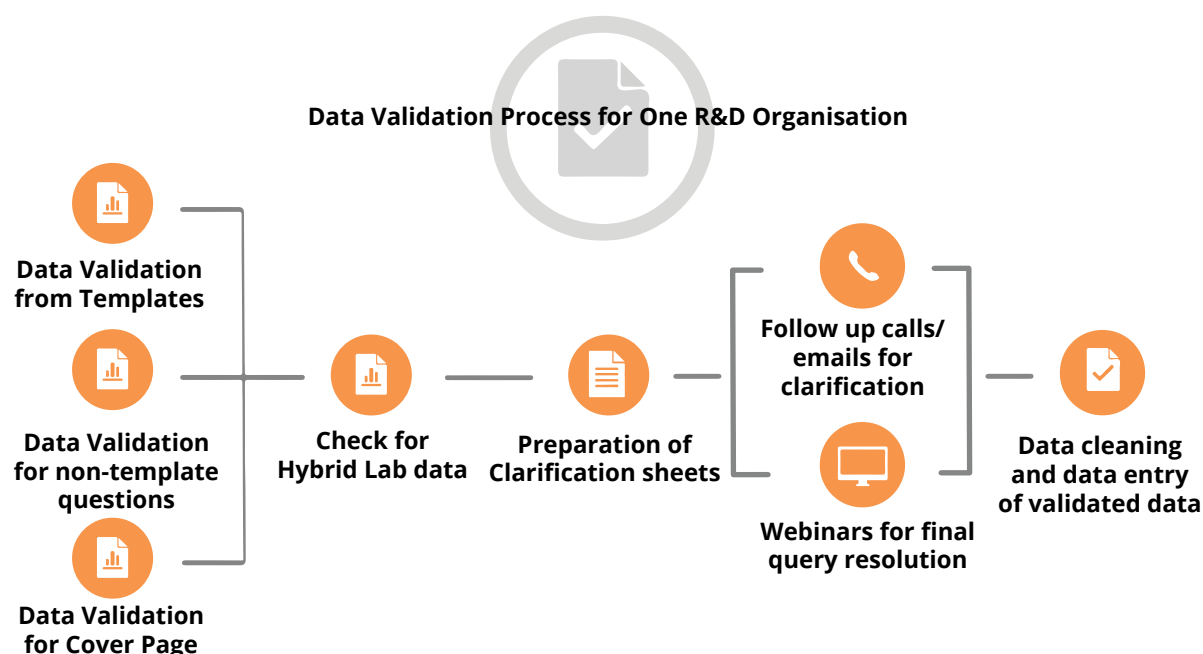
First, data entered through templates was compared with data reported in the online instrument, followed by data validation for questions that did not require templates as supporting documents. A similar process was followed for the validation of cover page data.

An additional step for validation was conducted for laboratories that identified themselves as hybrid. This was done to ensure consistency in responses under different categories the labs may have responded to.

Post validation of all the required data points, all inconsistencies were reported as queries and a comprehensive clarification sheet was prepared for each lab. These sheets were then shared with the respective laboratories and multiple follow-up calls and emails were exchanged in order to facilitate the resolution of the identified queries.

Additional assistance, where possible, was provided to laboratories based on their individual requirements. This was done through calls with the Nodal officers, for example facilitating collaborations with other labs to access their publication related information on Scopus or Web of Science.

There were also 4 webinars conducted for final query resolution and to inform labs about the templates they would be receiving.

Chapter 4
METHODOLOGY

In this chapter we highlight the approach undertaken for the purpose of analysis. Once the data had been validated and queries resolved with the labs, the corrected data was inputted wherever available. For the purpose of analysis the data that could not be validated was also considered. Wherever necessary, the data was also treated for outliers. The analysis can be found in Section 2 of the report, while Section 3 of the report presents individual lab data.

4.1 Analysis of the 193 Labs

Chapter 5 captures the aggregate picture of the 193 participating labs. The aggregate data is presented year-wise for each of the three reporting years i.e, 2017-18, 2018-19 and 2019-20. The six questions which were specific to Basic and Applied Labs, and seven questions which were specific to Services labs have not been considered for the aggregate analysis.

For the analysis of the labs in Basic, Applied and Services categories, covered in chapters 6, 7 and 8 respectively, the focus was on key indicators in various sub-pillars and hence pillars. Each chapter also has a spider chart that reflects the average performance of the labs under each category across the 11 sub-pillars. The average pillar-wise performance for each category of lab is also presented in the respective chapters. The methodology used to derive the performance scores of the sub-pillars and the pillars can be found in the Appendix.

For the charts presented in chapters 6, 7 and 8, the indicators were scaled using either the total budget of the lab or the number of scientific staff at the lab (scientific staff included permanent scientists as well as contractual researchers hired for projects).[1] This was to ensure comparability across labs. While most numeric responses were scaled by the lab's budget or scientific staff, binary responses and data reported as percentages were not scaled.

Since the data was reported for three financial years, the scaled data and other numeric data were averaged over the three years before the final analysis was undertaken. The individual lab responses for the three reporting years can be found in Section 3 of the report. The following section explains the methodology for preparing the individual lab sheets.

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[1]The scaling factors were in consultation with the statisticians nominated by the Office of the PSA.

4.2 Preparation of Individual Lab sheets

Individual lab sheets provide the raw data submitted by labs scaled by either the budget of the lab or the scientific staff at the lab. The numeric data has been adjusted to two decimal places. The sheet contains information on the lab's mandate, location, thrust areas of research and type of R&D performed.

The data submitted by the labs had been validated using supporting documents and templates, the step by step process of validation has been explained in Chapter 3. During the validation process, labs were approached to provide clarifications to certain responses. Where the labs did not provide any clarification, the data has been presented in its original form (scaled by budget or scientific staff where appropriate). The data that could not be validated were marked in a separate colour.

In addition to the responses for each of the three years, the lab sheet also displays performance of the lab indicator wise. In order to determine the performance of each indicator, the three year average of the scaled responses of the labs was taken and assigned a colour code depending upon the quartile to which the response belonged. The responses of all 193 labs were taken into account when computing the quartiles for the indicators except those that were specific to Basic, Applied or Services Labs. For the indicators that were specific to Basic, Applied or Services labs, the set of responses in each category of lab were considered when computing the quartiles. The colour-codes for different quartiles is explained in Figure 4.1.

Figure 4.1 Methodology for presenting indicator performance on the lab sheets

Step 1: Lab response received and validated	
Step 2: Numeric responses scaled using either total budget of scientific staff	
Step 3: Quartile calculated based on the average scaled response over the three reporting years	
Colour codes for the quartiles	1st Quartile
	2nd Quartile
	3rd Quartile
	4th Quartile

Presenting information by each indicator is intended to provide forward guidance to the labs to consider opportunities that may become an area of focus for them depending on their mandate. There are instances however where a large number of labs responded with a zero for a particular indicator, and hence all labs may appear in the top quartile for that indicator. Labs, nevertheless may wish to consider these indicators when defining their areas of focus going forward.

FINDINGS - INNOVATION EXCELLENCE INDICATORS
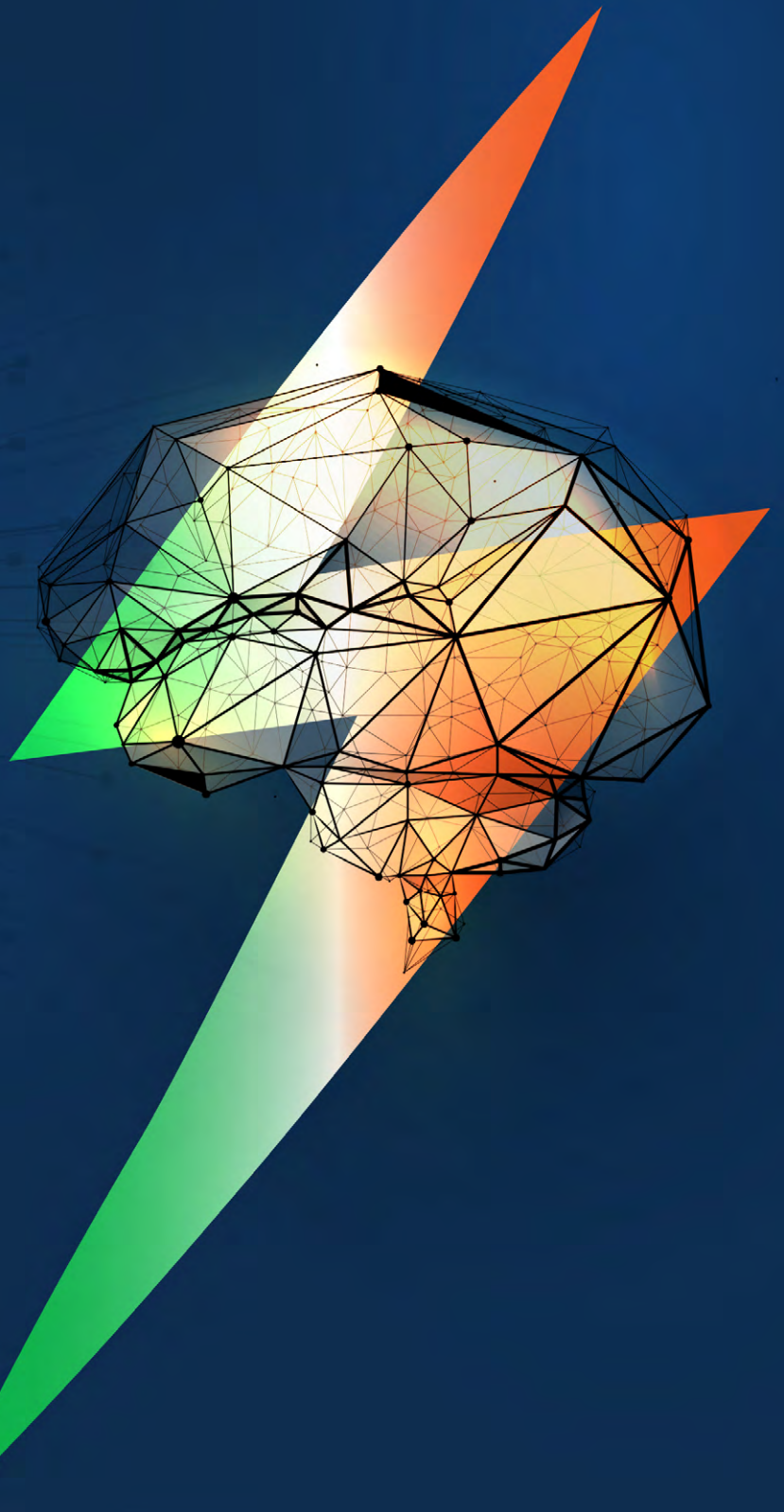
Chapter 5
THE PUBLIC R&D LANDSCAPE

India's publicly funded R&D institutions, that include laboratories from key scientific agencies as well as other central government departments, account for around 50 percent of India's national R&D spending. The key scientific agencies comprise departments undertaking research of strategic importance such as the Defence Research and Development Organisation (DRDO), Department of Space (DoS) and Department of Atomic Energy (DAE) as well as those undertaking other scientific research like the Council of Scientific and Industrial Research (CSIR), Department of Science and Technology (DST), Indian Council of Agricultural Research (ICAR), Indian Council of Medical Research (ICMR), Department for Biotechnology (DBT), Ministry of Electronics and Information Technology (MeitY), Ministry of Earth Sciences (MoES) and Ministry of Environment, Forest and Climate Change (MoEFCC). With respect to the other central government departments that are also contributing to India's R&D efforts include the Department for Promotion of Industry and Internal Trade (DPIIT), Ministry of Textiles, Ministry of Heavy Industries and Public Enterprises etc.
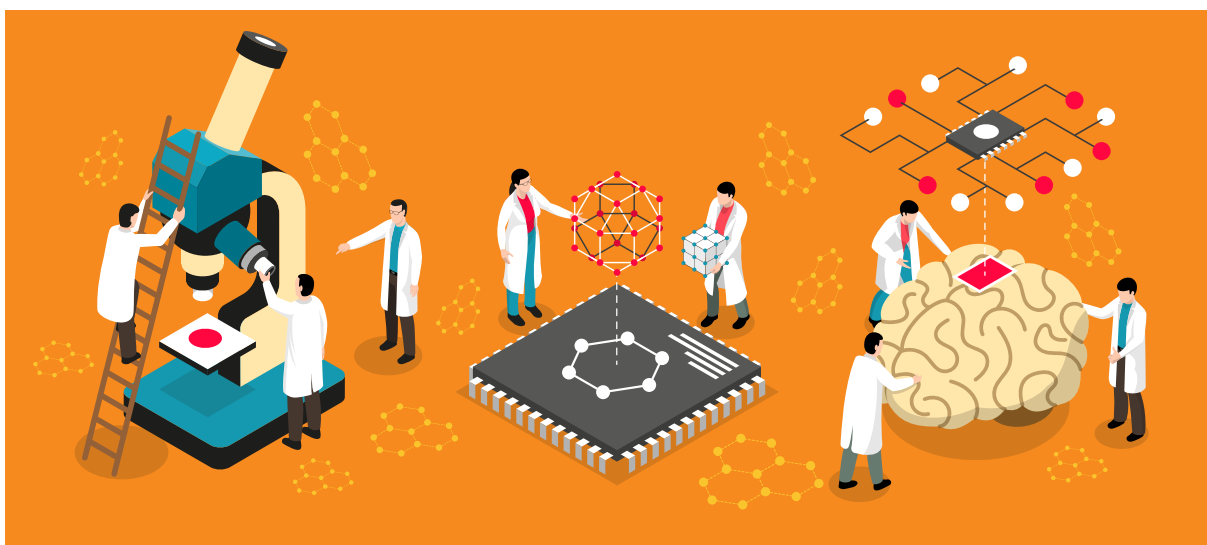
Figure 5.1 Central Government spending accounted for 50 percent of total National R&D Spending in 2017-18

7%
Higher Education Sector

50%
Central Sector

Total National R&D spending Rs. 1,13,825 Cr

37%
Private Sector

6%
State Sector
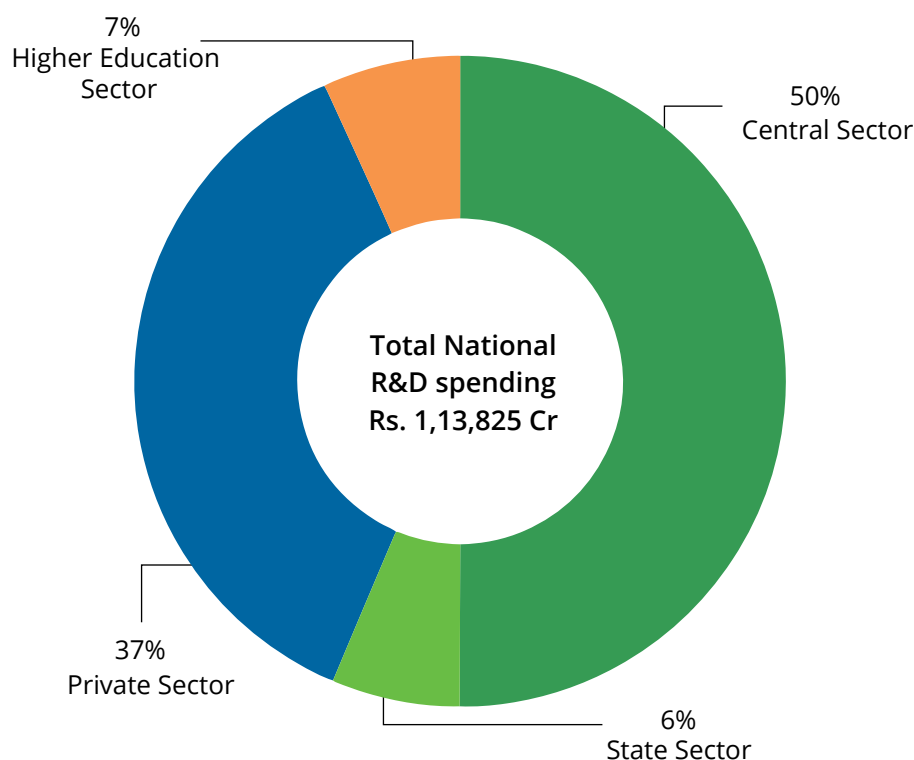
Source: Department of Science and Technology (DST), Government of India

The details of Central Government R&D expenditure when broken into three components, namely Strategic R&D labs (DRDO, DoS, DAE), key scientific agencies (excluding Strategic R&D labs) and other central government departments have been captured in Figure 5.2. The Strategic R&D labs requested to be exempted from participating in this study, and thus the 193 labs participating in this study belong to a set of departments and agencies that account for 48 percent of Central government expenditure on R&D. According to DST data, Central government expenditure on R&D was around Rs 56,920 Cr in 2017-18. The average over three years of the total budget for the 193 labs participating in the study was around Rs 12,914 Cr. Thus the labs covered in this study roughly account for over 45 percent of the spending by key scientific agencies (excluding Strategic R&D labs) and other central government departments, and around 11 percent of national R&D.

Figure 5.2 Ministry/Department wise distribution of the total R&D undertaken by the Central Government (2017-18)

16%
Ministries/Departments
other than the Major
scientific agencies

52%
Strategic
R&D Labs

32%
Major scientific agencies
(excluding Strategic R&D
labs)
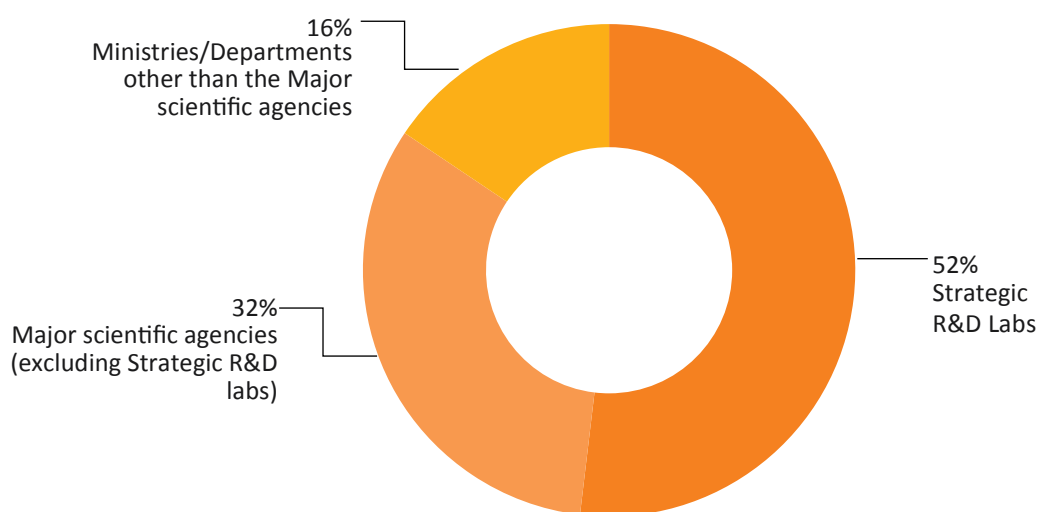
Total R&D undertaken by the Central Government: Rs. 56,920 Crores

Source: Department of Science and Technology (DST), Government of India

The labs being covered in this study are impacting the wider economy in a variety of ways. Their research and contribution not only have implications for the domestic economy, but also offer opportunities that can be of direct impact to the global community. While the department wise breakdown of the labs provided above may suggest a demarcation in the nature of research being undertaken, a closer look at the impact and the areas of research suggest some broad overlapping themes that cover various aspects such as healthcare, agriculture, energy and environment, transport and infrastructure, livestock and industries like food processing, textiles etc.

The labs covered here are a repository of knowledge in the above mentioned thematic areas and are playing an important role in addressing a number of societal and developmental challenges. A number of labs are also involved through their training programmes in addressing challenges with respect to livelihoods in remote areas of the country. We have more recently seen some of these labs being at the forefront in the fight against COVID-19, especially in the development of RT-PCR kits, genome sequencing of the virus as well as the vaccine. This study covers a period prior to the onset of the pandemic, and we highlight through examples some of the key contributions of these labs:

Healthcare

Labs in this sample are involved in biomedical research and perform a number of important functions like **support for diagnosis of outbreaks of virus diseases of public health importance,** data gathering, development of therapeutics, design and development of medical devices and other technologies, technical and scientific support with respect to nutrition and health as well as finding practical solutions to the many healthcare challenges that India faces.

In keeping with India's health needs, labs have developed world-first, cost-effective solutions for the diagnosis and treatment of diseases such as **Next Generation Sequencing (NGS) to identify rare Primary Immunodeficiency disorders (PIDs). Other innovations include the prototype of seeTB device as a cost effective, portable unit for detecting the causative agent of tuberculosis**, Mycobacterium tuberculosis (M.tb) in sputum samples, rapid and indigenous diagnostic kits which are now being used in the NTEP for diagnosis of TB and the LAMP assay suitable for diagnosis and assessment of cure of Leishmania infection.

Labs are also playing an important **role in generating valid data on disease epidemiology, hospital based surveillance, vaccine research, antimicrobial resistance, HIV sentinel surveillance including early infant diagnosis** which is leveraged by Public Health and Clinical stakeholders in effective decision making. For example, the National Cancer Registry that looks at using emerging technologies like big data analytics to improve clinical management, screening programs and cancer advocacy activities, other indigenous software applications such as the **NCDIR electronic mortality (NCDIR e-Mor) software application aim to strengthen the cause of death information system in India**.

The sample also includes **labs that are involved in the development of medical devices and technologies** for immediate application in the treatment or prevention of disease contagion. These include **Gelsolin Estimation kit to predict preterm birth for pregnant women, the Poorti-Breast prosthesis for post-mastectomy patients, TB filtration device-for improved smear microscopy**, Aptadx TB-semi-automated aptamer-based diagnostic for TB, green carbon technology for cheaper manufacture of drugs near patent expiry, typhoid detection kit, an indigenously developed Dyslexia assessment tool (DALI), Divya-Nayan- a portable reading machine for visually impaired, Electrostatic Disinfection system, etc.

Labs are involved in **other diverse activities such as contributing to policy, issuing health advisories, training and outreach at the community level** as well as liaising with international and national bodies to improve health and well-being of people.

Agriculture

Agriculture is arguably the most important sector in India with a large percentage of the population engaged in practising agriculture and allied activities. Thus, scientific advances in these fields have tremendous direct and indirect impact on the lives and economic progress of the country. Labs in this sample are involved in **basic and applied research that leads to improvement in crop productivity through agricultural mechanisation, harnessing energy from renewable sources, efficient management of irrigation water, reduction in post-harvest losses, disease diagnostic services,** conservation and

preservation of native species and breeds, etc. Some of their recent contributions are described below.

Labs are at the *forefront of development of seed varieties that can address nutritional, health and food security concerns.* These new varieties, coupled with improved agro-technologies, have significantly enhanced their farm incomes. Some notable examples include *Muktashree rice variety with low arsenic content in rice grain which has served immensely to the people affected by Arsenic related diseases*, Maize and bajra hybrids like PEEHM 5 and Pusa 23, respectively being of very short duration ensure food security in the rainfed area, high yielding and disease resistant varieties in different vegetable like okra (Pusa Bhindi-5), Cowpea (Pusa Dharni) that reduce the cost of cultivation and minimise the risk to the environment by way of avoiding the use of pesticides. Apart from these, there are a *number of wheat and basmati rice varieties that contribute significantly to agricultural exports*. Samba Mahsuri Rice variety, which has bacterial blight (BB) resistance, has higher growth prospects than traditional strains of rice and utilises less water, making it a good candidate for high social returns.

Labs are *focussed on horticulture and have developed commercially viable flower varieties* and also engaged in research on medicinal and aromatic plants. India has become the largest producer of mint oil. Cultivation of aromatic crops like lavender, saffron, marigold, lemongrass in barren and underutilised areas has increased farmer incomes, especially in the Himalayan region. R & D programmes on captive cultivation of high value medicinal plants such as Tinospora cordifolia and Gymnema sylvestre, Commiphora wightii and Dioscorea deltoidea and identification of elite chemotypes based on chemical markers and mass multiplication for producing quality planting materials has resulted in the production of quality plant material for industrial applications.

Benefits derived from a particular technology are mainly reduction in cost of operation (due to enhanced capacity or saving of inputs like seed, fertilizer, labour because of their better application) and yield advantage due to increased inputs efficiency. These include beneficial microbes based interventions, such as novel biofertilizers, biopesticides and biostimulants, a green molecule formulation to increase cotton fibre yield and quality, bio-fortification of rice grains with Fe and Zn, using siderophore secreting microbes, Site Specific Nutrient Management technology. *The Pusa Decomposer, a microbial consortium, has been very effective in degrading the paddy straw and other agri-residues in short times*. When applied it degrades the paddy straw under in-situ conditions in 20-25 days.

Labs are also involved in maintaining and updating knowledge repositories like the *Comprehensive Cotton Genomic Database Developed, which is the world's largest Database on cotton and developed with diverse Indian genotypes to help cotton breeders to select genes* and markers for development of superior cotton varieties for the desired agro-climatic zone/ regions of the country and the National Repository of Indian Flora.

Labs are involved in other diverse activities such as contributing to policy on the framework for Ease of Doing Agriculture across states, Doubling Farmers' Income (DFI), agricultural market reforms including revision of the APLM and Contract Farming Model Acts, etc. They play an important role in training with various programmes on agro-entrepreneurship, pest management, farming practices, technology dissemination, etc.

Energy and Environment

The changing weather patterns have disrupted the lives and livelihoods of many, and the crisis is likely to get worse. Labs are working towards finding solutions to the plethora of challenges brought on by climate change. For instance, they **are developing and using new technologies to create warning systems, predict meteorological changes, combat pollution, etc.** Furthermore, labs are **conducting research on water, energy and minerals as well as assessment and mitigation of natural hazards such as earthquakes.**

Labs are using predictive technologies, satellite imagery and big data for predicting weather changes. The outputs of some of these **climate model simulations are shared with agencies engaged in preparation of State action plans** on climate change in various states. These **technologies are also critical in issuing advisories such as Tsunami Early Warning, Storm Surge, and Multi Hazard Vulnerability Services** have been providing accurate and timely tsunami advisories (within 10 minutes) to stakeholders (national and international), thus helping to reduce damage to life and property. Similarly, a meso-scale network including installation of different instruments was established in Mumbai for high resolution mapping of rainfall over Mumbai Metropolitan region. A mobile app 'Mumbai Weather Live' was developed to provide live location specific information on rainfall.

Weather data has also been used to devise pollution warning systems such as the Fog early warning system and different tools utilized by Delhi international airport (GMR and ATC-AAI) for cancellation and rescheduling the flights from/to IGI airport 10 hour in advance. **Air quality Early warning systems** and different tools developed for Delhi are utilized effectively by pollution control authority to restrict/impose/lift temporary ban construction activity, transport activity advisory for the schools and hospitals 72 hours in advance. Similarly, special efforts were made for monitoring of weather and pollutants and providing forecasts during Kumbh Mela 2019 in Prayagraj. A mobile app named 'KumbhMela Weather Service' was developed to disseminate live weather information.

Indigenously developed **shallow water remotely operated vehicles, sensors and sensor arrays are being used for exploratory research on marine life and oceans, deep sea mining, reduction of coastal erosion, deep sea drilling for gas hydrates, etc**. Some labs are working on technologies for pollution mitigation such as water purification technologies, soil testing technologies. A smart phone App containing a database of pollutant-specific 70 air pollution-mitigating plants with their images was developed and launched. Research is ongoing to identify plant species as potential mitigants of ozone pollution. These plants will help in improving the urban air quality and can have a large societal impact in terms of public health. Similarly, some labs are working on developing ozone resistant crop varieties.

Central databases like the Marine Meteorological Atlas (MaMeAT), Sound Velocity Atlas (SoVeAt), Digital Microwatershed Atlas of India are central to planning and research efforts by other R&D institutions.

Transport and infrastructure

Transport and infrastructure are critical to a nation's progress. Labs are working on new *materials, efficient fuels, maintenance technologies, eco-friendly solutions to improve existing transport and infrastructure setup.* Some notable examples include technology of *Avionics Head-Up Display test rig for testing and maintenance activities related to HUDs for Tejas Aircraft and its variants*, NVG compatible LED lights for Helo Deck Visual Landing Aid System, *conversion of fine particles of Kota stone processing industry into value added building products like paver block, foamed walling blocks, tiles etc*. for effective utilisation of the environmentally risky material, geo-polymer as a replacement of cement in heavy duty / medium duty pavements, etc.

Other technologies like *reinforced concrete protective coating technology have resulted in reduced water permeability of the concrete surface / increased* corrosion resistance, thus enhancing the service life of Nagpur, Chennai and other Metro rail bridge girders. *Indigenous technologies like "Pothole Repair Machine" and "Mobile Mixture cum Paver" for laying and maintenance of pavement have reduced costs*. Other methodologies and technologies for *utilisation of various waste materials such as Fuming Furnace (FF) Slag, banner flex waste, C&D waste in road conduction works*, proposing cost effective solutions towards improved long-time durability of roads, reducing the life cycle costs, recycling of pavements, waste plastic roads and reduced carbon footprints resulted in sustainable road construction which enormously reduced the total cost of construction of roads.

Labs are working on the application of scientific and advanced methods (new technologies) viz. GIS, NSV, GPR, FWD etc. in *development and storing of road inventory data and road database*. Landslide control measures implemented by these labs at critical hilly regions and transportation networks have enhanced the productivity of mountainous states and have reduced the travel time of both man and material at many of the critical locations including those in the pilgrim routes of Chardham. *Similarly, development of Drone based technology is being deployed for inspection and testing of bridges to aid faster investigations and maintenance of existing structure*. Data is being used to prepare traffic circulation plans for urban intersections, areas around metro stations, cement plants etc. to facilitate smooth traffic movement to reduce traffic congestion and other ill-effects like air pollution and road crashes.

Utilising the locally available materials and catering to rural housing, labs have worked on *design templates (for different geo-climatic and hazard zones of India) for a cost effective housing scheme*, within the budget constraints of PMAY. The cost per square feet of 7 USD is noteworthy and of global significance. Indigenously developed technologies on confined masonry were used in the rebuilding of the earthquake damaged school and health infrastructure of Nepal. Another noteworthy example is the development of specialised *Anchor foundations for Up-lifting loads Solar power plant foundation, which are the critical elements in the solar power farms*. Cyclonic winds directly affect the solar plant foundations and result in loss and power outages in the solar power industry. This technology is reviving these losses. These labs also contribute to research on *maintaining the structural health of monuments of cultural and historic significance*. The

development of anti-termite phytochemicals based treatment of structures has resulted in loss minimisation and damage control measures for important structures, monuments like Golden Temple, Amritsar.

On the new materials front, a hybrid transparent electrode technology consisting of metal mesh and a very thin oxide overlayer has been developed. These electrodes have found various applications due to its very high transmittance (T~ 87%) and very low sheet resistance (Rs ~ 5 ohm/square) optoelectronic and related applications. We have explored various applications and developed various prototypes such as Smart windows, Transparent heaters, transparent EMI-shield, etc. Similar advances have been made in the application of steel and other materials.

Labs are also at the forefront of EV technology including the formulation and introduction of guidelines and standards for EV chargers, testing and validation studies, EV/HEV certification and development of new products.

Livestock

Labs are involved in various research aspects of livestock such as identification and conservation, developing new breeds, developing technologies to improve breeding, maintenance and health of livestock, disease surveillance, etc. Data is collected on various aspects of aquatic genome resources and provide technical backstop to several policy related bodies such as DADF (Ministry of Agri.& Farmers Welfare), National Biodiversity Authority, MPEDA (Ministry of Commerce). Labs use patented technology to identify species involved in illegal wildlife trade by furnishing reports to law enforcement agencies and are also involved in the documentation and registration of breeds of native livestock and poultry. Labs are working towards genomic selection in native cattle and buffalo populations and have created DNA Chips specific to indigenous cattle and buffalo breeds through utilising genome-wide SNPs information.

Labs are at the forefront of developing improved varieties for better yields and monetary returns. For example, improved chicken varieties improve the household income with additional income from sale of meat and eggs. Similarly, technologies on scientific yak rearing and yak product processing cater to highland farmers, where livelihood opportunities are scarce. Labs are catering to coastal and other marginal communities to promote livelihood development through identifying newer technologies like alternate management techniques for water-logged sodic soil for aquaculture purposes, mobile apps for better rearing and management of brackish water ornamental fish, shrimp, etc. An innovative Micro-nursery system has been developed for bivalve seed production mainly for green mussel Perna viridis.

Technologies developed by labs include a super-chilling cabinet with an accurate temperature and humidity control has enhanced the shelf-life of chicken and mutton, a novel method of converting fish waste to plankton booster to improve natural productivity in aquaculture ponds and mariculture technologies such as cage farming, cage design and deployment, ornamental fish farming, live feed culture, mussel and oyster farming, seaweed farming, algal culture and mass multiplication, image pearl production, etc.

Labs are involved in disease surveillance. The disease forewarning bulletin for 13 economically important livestock diseases was prepared using the National Animal Disease Referral Expert System (NADRES) and state-wise forewarning bulletin play an important role in animal disease control and prevention. Labs are also involved in the development of diagnostic kits for early detection of important and newly emerging diseases. Patented genomic technologies are also used in the early detection of diseases in wildlife populations.

Automotive, food processing, textiles etc.

Labs are also involved in industry specific research and development. Labs in this sample are spread across industries like food processing, automotive, textiles, rubber manufacturing, instrumentation, electronics, etc. They are at the forefront of developing new technologies for developing food processing units at individual, farm centric level, clean meat production, production of value added meat products, use of local ingredients such as millets, pulses, cereals, buckwheat, nuts and fruits to develop ready to eat and ready to reconstitute nutritious food products, such as energy bars, protein-micronutrient fortified bars, fruit bars, instant protein energy rich premixes, and herbal Khichadi, technologies for banana fibre extraction, Mushroom Cultivation, Production of Vermi-compost, Cultivation & Processing of Medicinal & Aromatic Plants and Home-Made Paper , etc all play an important role in the agro-entrepreneurial space.

Research programmes on forest genetics and tree breeding intertwined with advanced technologies for species like Teak, Casuarina, Eucalyptus and phyllodinous Acacias have yielded productive varieties and quality seeds contributing to the paper and pulp industry. Similarly, technological advances in transfer and adoption of improved post cocoon technology packages and introduction of the State -of -the art technology in silk reeling i.e. Automatic silk reeling technology to handle bulk quantity of cocoons and suitable for large scale production of superior grade raw silk consistently has greatly helped the textile industry.

The sample includes labs focussed on testing and quality certification, product development and customised training activities in niche industries like rubber manufacturing, cement industry, automotive industry, mining and coal industry. Some notable examples include the development of a Smart Sensing System for Cold Drawn High End Wires, Self-healing Coating for Corrosion Protection of Steel and Aluminium Alloys, Annealing simulator integrated with online process control sensors for run out table process simulation, scale up and commercialisation of indigenously developed hydrogen standard in steel. Processes and technologies for the extraction of precious metals (Au, Pt and Pd) from the electronic waste is another important area of contribution by these labs.

Labs are contributing significantly to digital technologies and infrastructure in the country. The ERNET VSAT connectivity benefits remote schools and educational institutes located in the remote parts of India. Smart Virtual Classroom project has greatly benefitted students in remote areas. These labs have also developed a number of citizen centric services such as eSign, Mobile Seva, ePramaan, Vikaspedia etc. Language barriers have been alleviated through speech based technologies and translation tools developed at these labs.

The examples provided above, while not exhaustive, are meant to give the reader a glimpse of the far reaching impact the labs are currently having. While the framework developed to evaluate the science indicators does take into account the impact on the direct beneficiaries of the labs programmes, it also offers the labs an opportunity to re-assess and perhaps recast themselves in ways to engage with India's R&D ecosystem and the wider community both domestically and globally to create wider impact. For example, while a number of labs are engaged in training programmes that focus on entrepreneurship, less than 20 percent of the 193 labs are engaging with the start-up ecosystem. Thus while the contribution to job creation may be taking place through the training programmes, fewer employment opportunities are being generated through the startup route due to the lack of incubation activities at several labs. And while the total number of technologies developed between TRL 0 and 4 and TRL 5 and higher, that are targeting SDGs and national programmes have been steadily increasing over the three years under consideration, the earnings by way of commercialisation appears relatively low compared to activities like training. The transfer of these technologies has largely been domestic, and it is very likely that many labs are mandated to transfer these technologies for free to address the various social and economic problems in the country. Undoubtedly, this has benefitted the domestic economy including several communities in remote regions of the country as highlighted in some of the examples above. At the same time what is also evident from the data is the lack of industry collaborations as well as international collaborations on projects. Plugging into the global research ecosystem as well as partnering with industry may pave the way to offering home grown solutions to several global challenges while providing the labs an opportunity to diversify their sources of funding and revenue. There is a wealth of information that emerges from the data that follows, and the public research ecosystem could use the framework developed to constructively complement and at the same time scale up some of their existing activities to benefit India's R&D ecosystem more widely.

In the sections that follow we look at the contribution of India's publicly funded R&D labs, not just to society at large, but also in terms of its contribution to India's scientific output and innovation outcomes. Before delving into details on output and outcomes, we first begin by briefly describing the institutional capabilities and practices of the labs.

5.1 Institutional capabilities and practices

5.1.1 Median of share of spending on R&D and S&T in overall budget is below 40 percent

While the mandate of the labs is one of mainly performing R&D, many labs have reported a low level of spending on R&D and S&T as a share of their overall budget. The R&D and S&T expenditure as a share of the budgets of the labs has a median value that ranges between 37 percent and 39 percent over the three years. Around a third of the labs did however respond that they were spending between 75 percent to 100 percent of their budgets on R&D and S&T activities. The R&D and S&T expenditure is meant to capture all costs related to research including salaries and travel costs, and excludes administrative running costs. It may be that labs have under-reported their spending on R&D and S&T. As we shall see below, nearly 40 percent of labs have not deployed any software to track and manage their projects from conception to completion, and hence it may be that true research related costs are not being captured in their entirety.

Figure 5.3 Labs have reported low share of spending on R&D and S&T in overall budget
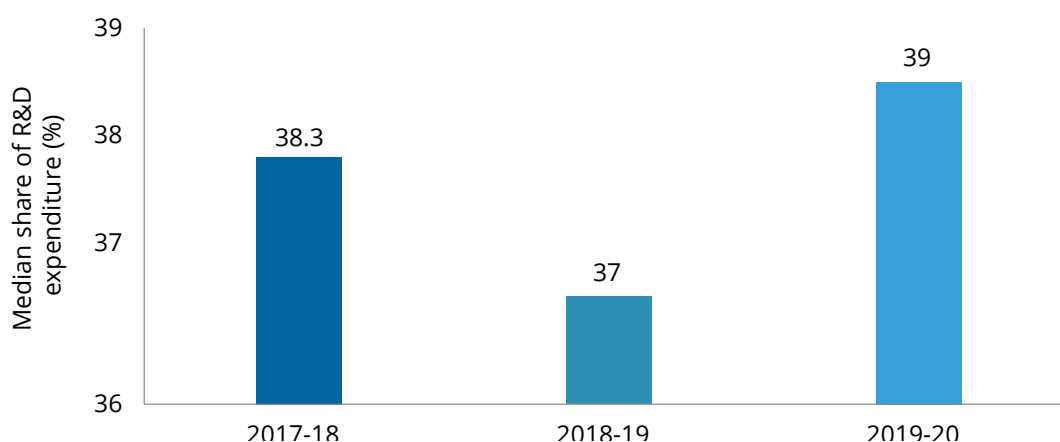
5.1.2 Share of contractual researchers in total scientific staff increasing

The charts below show a gradual decline in the number of permanent scientists for the 193 labs while there has been a growth of around 8.6 percent per annum in the contractual research staff. The number of labs reporting a drop in their permanent scientific staff was 84 in 2019-20 compared to 69 labs in 2017-18.

Figure 5.4 Number of permanent scientists
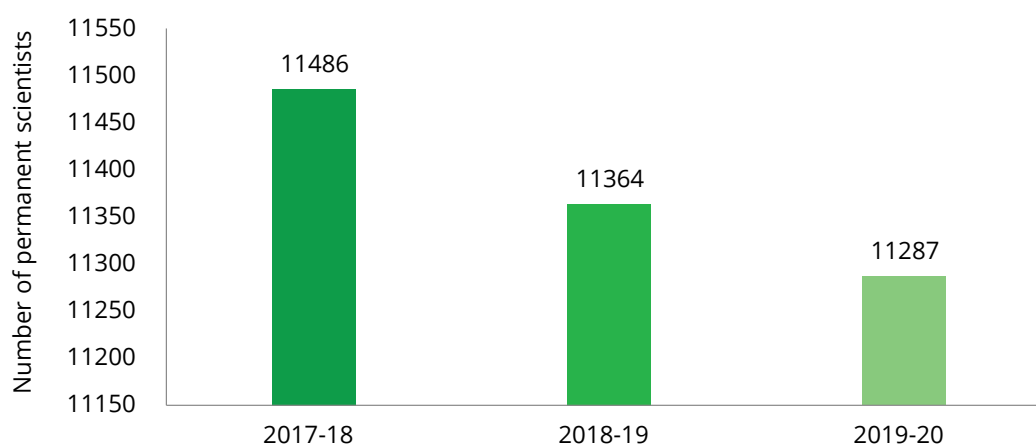
Figure 5.5 Labs seeing a drop in number of permanent scientists have increased
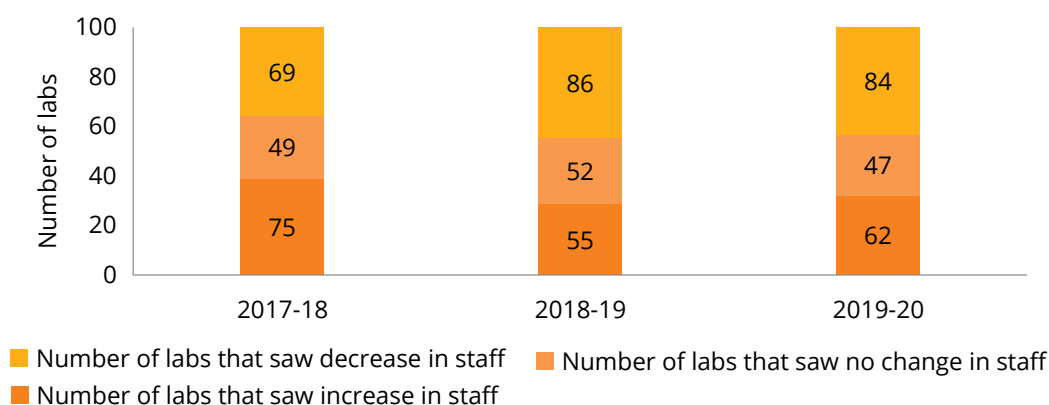
With respect to contractual research staff, the increase in contractual researchers from 2017-18 to 2018-19 was accompanied by more labs reporting hiring contractual researchers over the same period. However, the increased hiring of contractual researchers between 2018-19 and 2019-20 was led by fewer labs, with just 91 labs in 2019-20 showing an increase in their contractual research staff compared to 114 in the previous year. In 2019-20 there were also more labs that showed a decline in their contractual staff compared to 2018-19.

Figure 5.6 Labs have seen 8.6 percent growth per year in contractual researchers
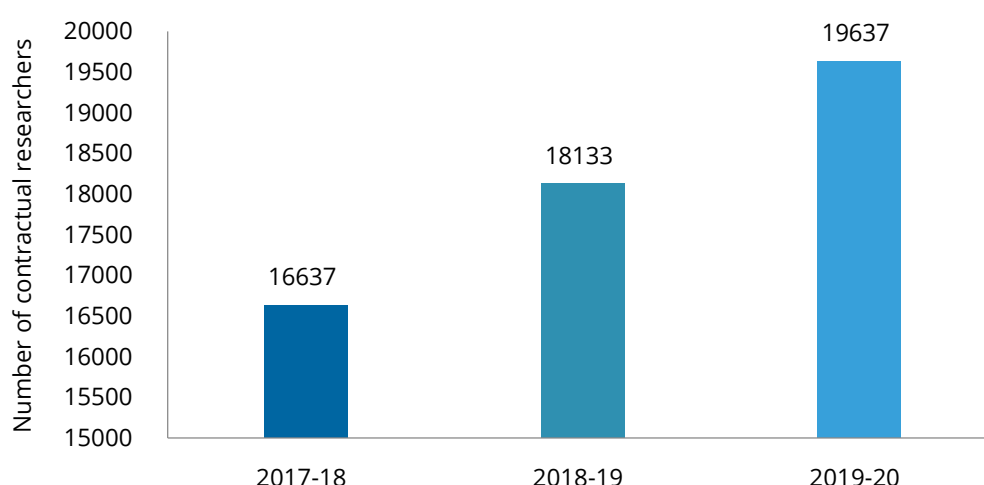
Figure 5.7 Number of labs reporting a drop in contractual staff increased in 2019-20

- Number of labs that saw decrease in staff
- Number of labs that saw no change in staff
- Number of labs that saw increase in staff
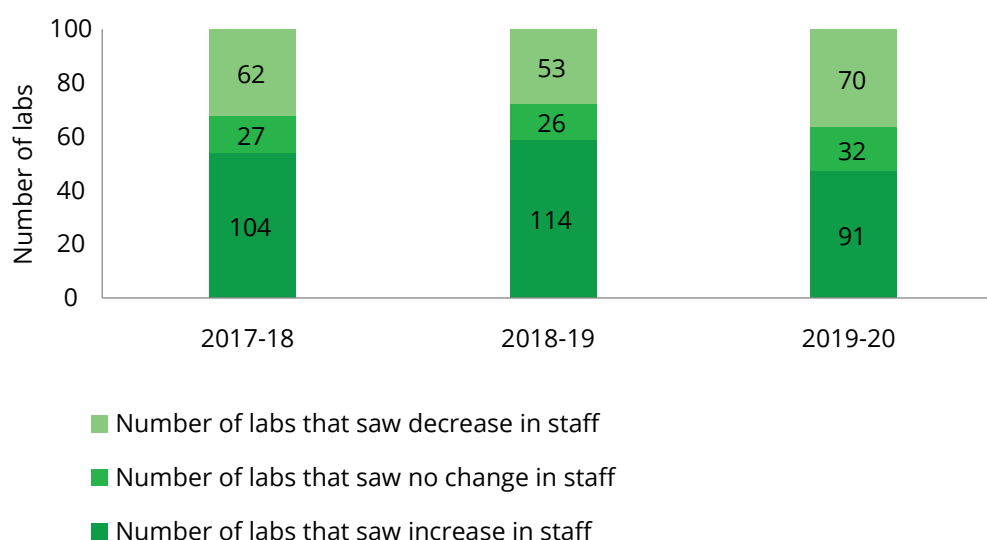
The median value for the share of scientists in overall scientists increased to 54.1 percent in 2019-20 from 51.6 percent in 2017-18 on the back of increased contractual research staff. In the data on overall staff and scientific staff, a handful of labs belonging to some of the key scientific ministries as well as some organisations engaged in educational activities reported contractual research staff running into thousands.

Figure 5.8 Share of scientific staff (%)
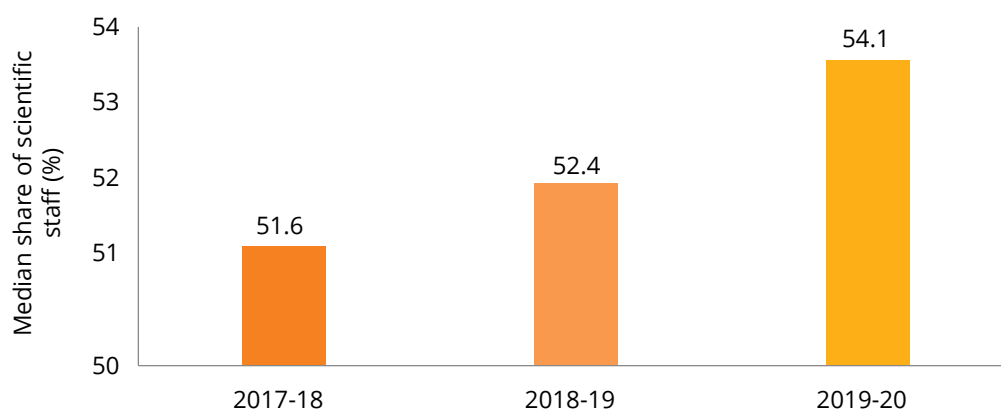
5.1.3 Scope to increase share of women researchers in overall scientific staff

As can be seen in Figure 5.9, there has been a steady but nominal increase in the median value of the share of women researchers in scientific staff between 2017-18 and 2019-20. However the share remains low at 30 percent in 2019-20. Every effort should be made to increase the participation of women in the STEM workforce.

Figure 5.9 Efforts should be made to increase women participation in STEM workforce

5.1.4 Young researchers as a share of the scientific staff

When it comes to young researchers as a share of the scientific staff, the median value here has remained steady between 63 to 65 percent over the three year period. Young researchers here by definition are below the age of 40. In 2018, India reported a total of around 26,566 PhDs being awarded, the third highest worldwide.[2] Efforts should be made to attract many more young r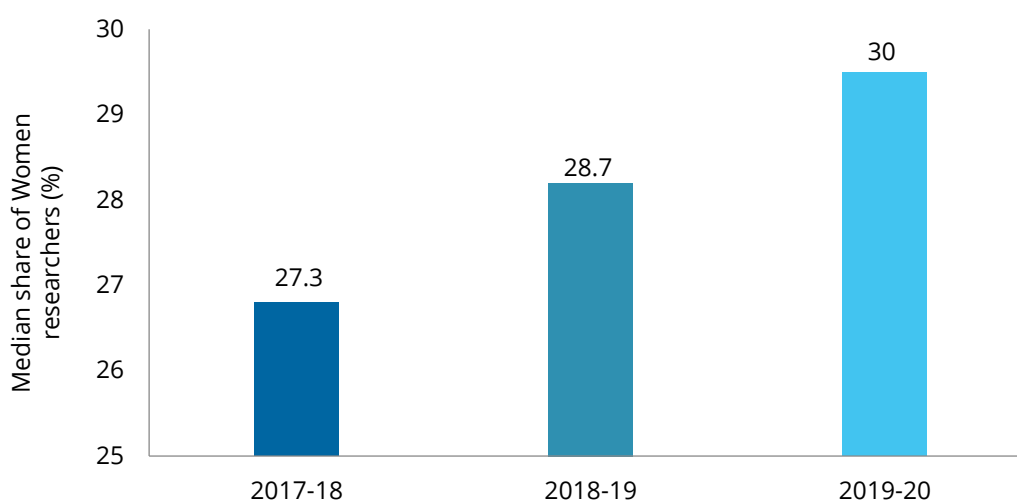esearchers from this talent pool to contribute to the scientific endeavours of the publicly funded R&D labs. If the reported data on R&D and S&T spending as a share of the overall budget is indeed that low, then there is definite scope to absorb some more of the emerging young talent pool, with possibly an emphasis being placed on hiring of young women researchers.

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[2]CTIER Handbook: Technology and Innovation in India 2021

Figure 5.10 High share of young researchers in scientific staff
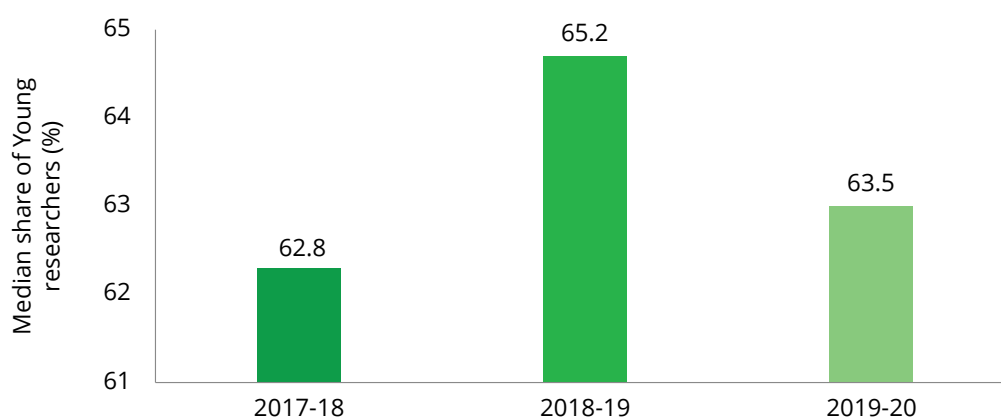
5.1.5 Support provided to outside researchers

The number of outside researchers supported by the labs increased over the period under consideration. Outside researchers include teachers, university faculty, doctoral students, scientists from other institutions and industry. This trend is an encouraging one and possibly driven more by researchers from other labs or academic institutions compared to researchers from industry. As we shall see below, less than 40 percent of the labs have collaborations with industry. Promoting stronger linkages with the higher education sector by sharing the labs facilities would mean encouraging college teachers and university faculty to spend time on research projects at the labs. Access to the labs' facilities could also be provided to independent researchers or startups as a service for a nominal fee.

Figure 5.11 Number of outside researchers supported
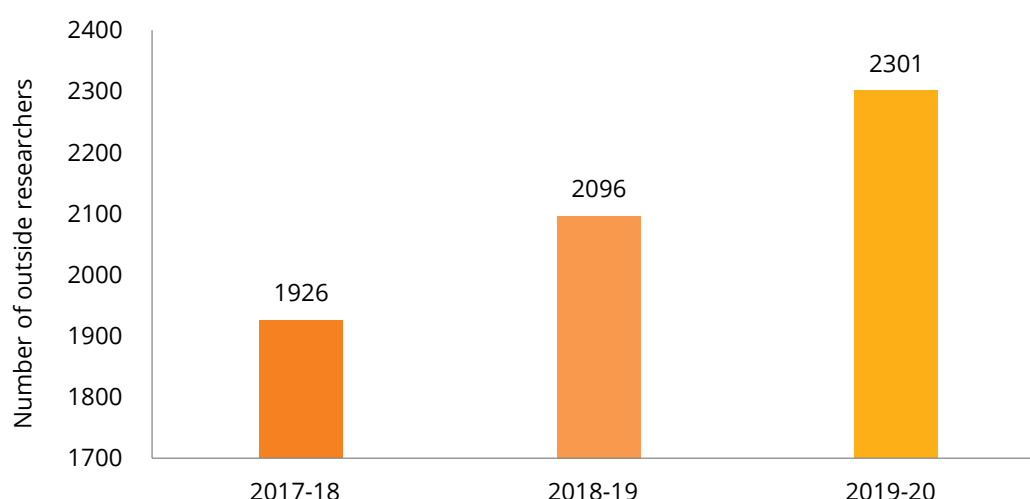
5.1.6 Labs are adhering to best practices on most policies and guidelines

In terms of policies and guidelines, labs are adhering to most of the best practices outlined in the framework. One area of improvement that around 40 percent of the labs would need to consider is in deploying a software system to track and manage their projects from conception to completion.

Table 5.1 Policies on ethics guidelines, sexual harassment and public grievance redressal in place

Question	Share of labs that responded 'Yes'
Does your organisation effectively communicate its objective and strategy to its staff?	100
Does your organisation have all requisite SOP/guidelines for its processes?	99
Are there initiatives in place to promote intra-organisational collaborations?	99
Has your organisation deployed any software system to track and manage research projects through its lifecycle, from conception to completion?	61.1
Does your organisation have necessary ethics guidelines and policies in place?	99
Does your organisation have a sexual harassment mitigation cell with requisite policies and procedures?	99.5
Does your organisation have a public grievance redressal cell?	95.9

As seen earlier, there is significant scope for labs to encourage greater women researcher participation in their workforce. One way to ensure that there is sufficient attention paid to achieving this important goal is to ensure that a lab has an active EDI cell or committee. At present only 35 percent of the labs said they had an EDI cell.

Figure 5.12 EDI cells an absolute necessity

35%
Share of labs that responded 'Yes' (%)

65%
Share of labs that responded 'No' (%)
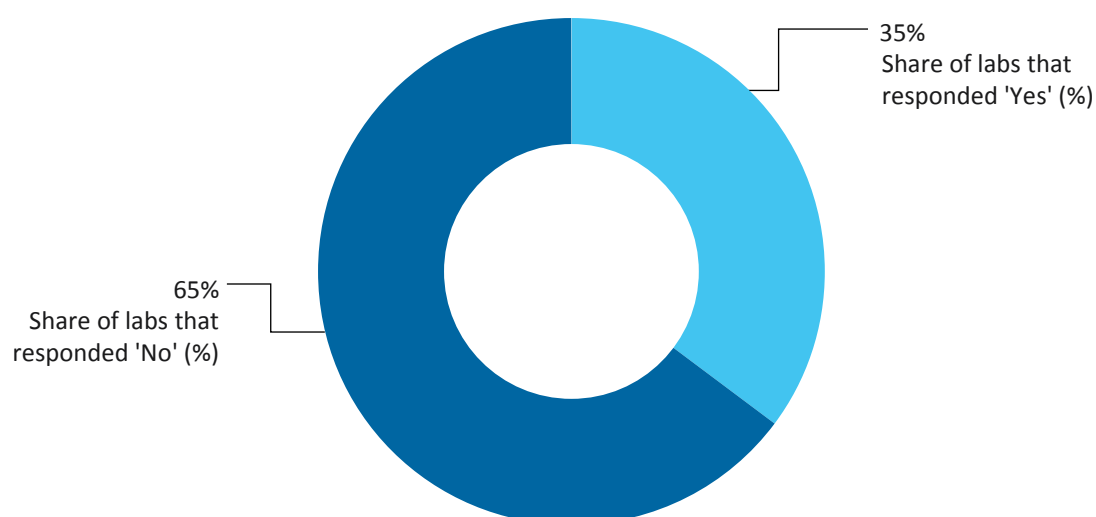
Around 90 percent of labs have made provisions for differently abled facilities. This is also an important EDI criteria that all labs should aspire towards fulfilling.

Figure 5.13 Provision of differently abled facilities

11%
Share of labs that
responded 'No' (%)

89%
Share of labs that
responded 'Yes' (%)
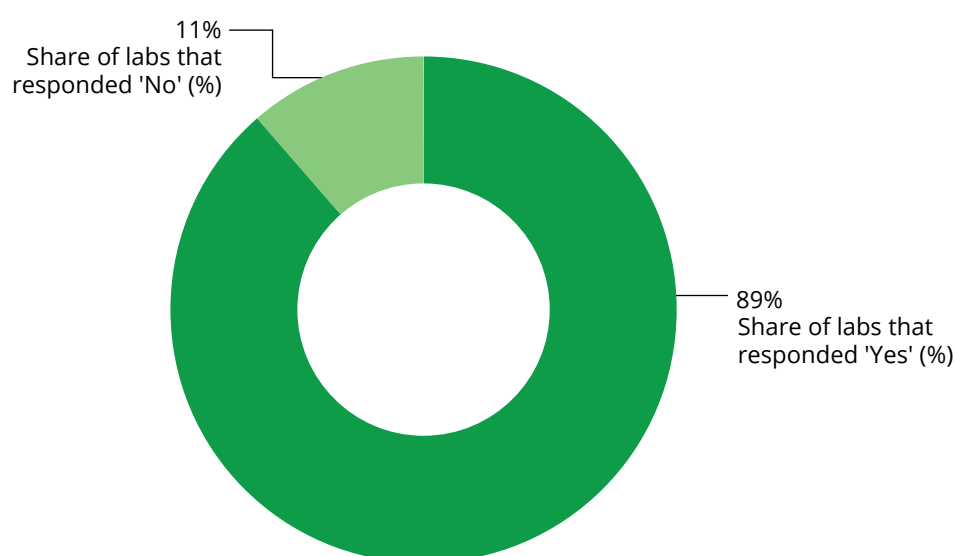
Other best practices, especially related to governance include having a website that captures details of the lab's R&D facility and its research manpower etc. as well as ensuring the website is updated on a regular basis. Almost all labs follow these practices. However around 30 percent of labs do not have a national or international accreditation for their lab procedures. This would be an important element for labs to ensure that all necessary certifications are in place, especially if the labs are to ensure increased collaborations with industry or even participate in international projects.

Table 5.2 Only 70 percent of labs have national/international certification for their lab procedures

Question	Share of labs that responded 'Yes'
Does your organisation have national/international accreditation/ certification for its lab procedure?	69.8
Does your organisation have transparent recruitment guidelines and processes in place?	100
Does your organisation's website capture details of your R&D facility, research manpower and mandatory disclosures?	99.5
Are website updates and maintenance carried out as per schedule?	99

5.1.7 Capability development of staff

Around 95 percent of labs said they had incentives in place to promote talent while around 98 percent of labs had a structured career progression plan in place for their scientific staff. While these are good and important management practices that the labs have, the spending on training of their staff remains close to or less than 1 percent of the total budget for most labs.

Figure 5.14 Several labs have incentives in place to promote talent

5 — Share of labs that responded 'No' (%)

95 — Share of labs that responded 'Yes' (%)
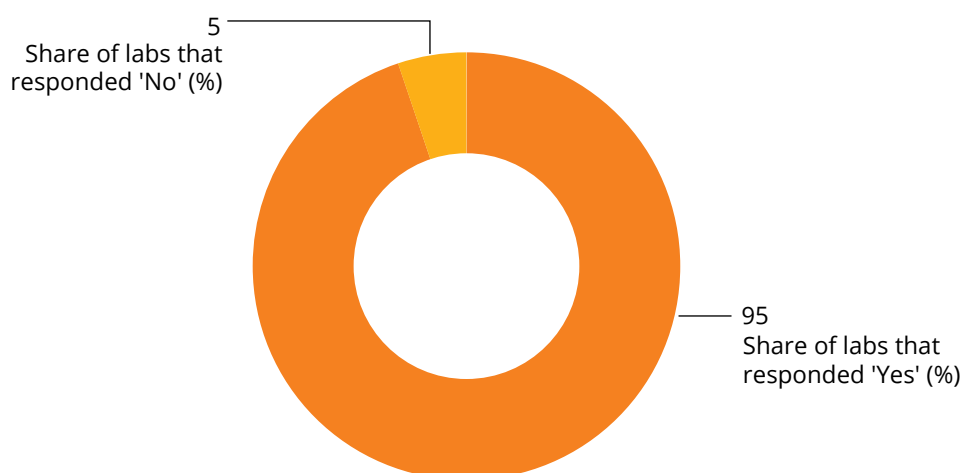
Figure 5.15 Structured career progression plan for scientific and non-scientific staff: nearly all labs have a structured career progression plan in place
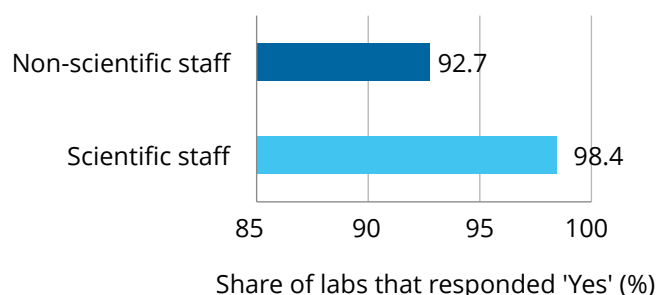
Non-scientific staff 92.7

Scientific staff 98.4

Share of labs that responded 'Yes' (%)

The spending on training of staff by the labs has been gradually increasing in the three years under consideration. This should continue and with a higher share of the budget possibly being allocated towards the continuous skills upgradation of the staff to keep up with the rapidly evolving technology changes globally. Investing in the skills upgradation of the staff would complement the otherwise good incentive mechanisms in place to boost the productivity of the researchers.

Figure 5.16 Amount spent on training has been rising

Amount spent on training (Rs. Crores)

2017-18 132.1
2018-19 143.6
2019-20 145.3
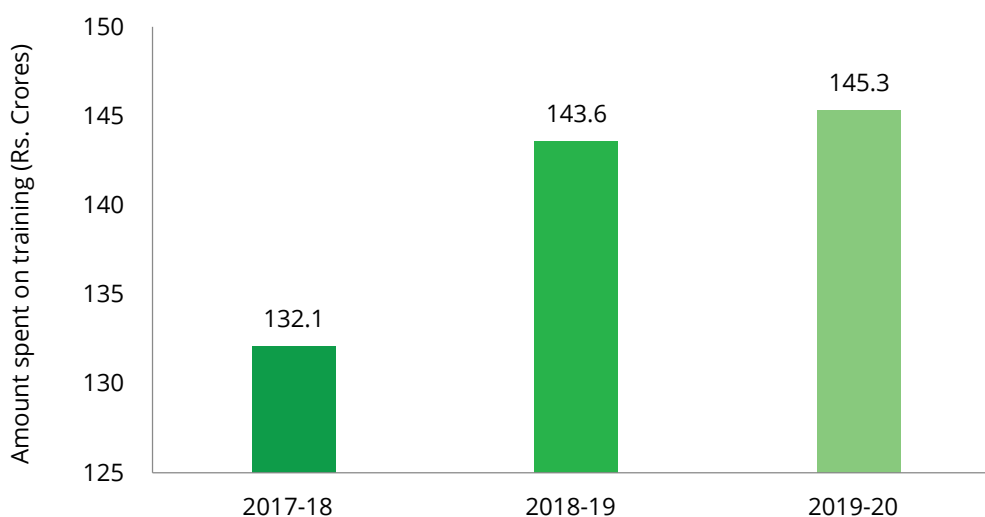
5.2 Scientific output and innovation outcomes of the labs

5.2.1 Projects undertaken increasing but share of industry collaborations remains low

As can be seen in Figure 5.17, there are 112 labs that have a budget upto Rs 50 Cr, of which 71 have an average budget less than Rs 25 Cr. There are 40 labs that have an average budget between Rs 50 Cr to Rs 100 Cr, while 41 labs have an average budget above Rs 100 Cr. The findings in Table 5.3 suggest as would be expected that the median value for the number of projects being undertaken increases with higher budgets.

Figure 5.17 Distribution of labs by budget category
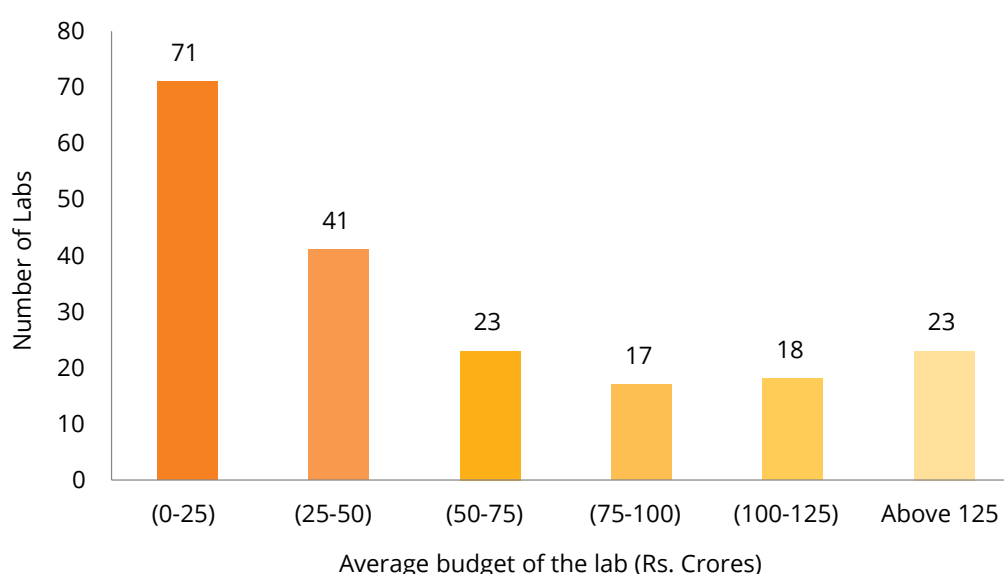
Table 5.3 Median number of projects based on budget category

Budget of the labs (Rs Crores)	Number of Labs	Median number of projects executed
0-50	112	31
50-100	40	58
Above 100	41	95

Labs were requested to respond to the number of projects they were undertaking during each of the three years. The projects that were started or completed in a particular year as well as those that were multi-year projects and ongoing had to be considered where applicable. It was likely that a multi-year project was counted in each of the three years under consideration as requested for by the framework.

Between 2017-18 and 2019-20, the total number of projects being undertaken by the 193 labs increased from 11,500 to around 12,900. However, as can be seen in Figure 5.18, only 37 percent of labs were engaged in collaborations with industry in India, and around 8 percent of labs were collaborating with industry overseas. The share of industry collaborations in total projects is very low.

Figure 5.18 International and National industry project collaborations
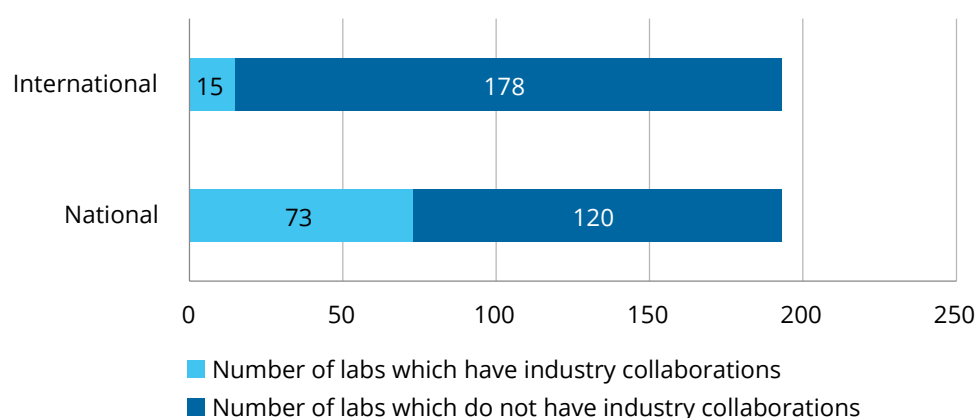
For academic collaborations, there is a higher share of national academic collaborations as compared to international academic collaborations on projects.

Figure 5.19 Share of academic collaborations in projects executed by the labs (%)
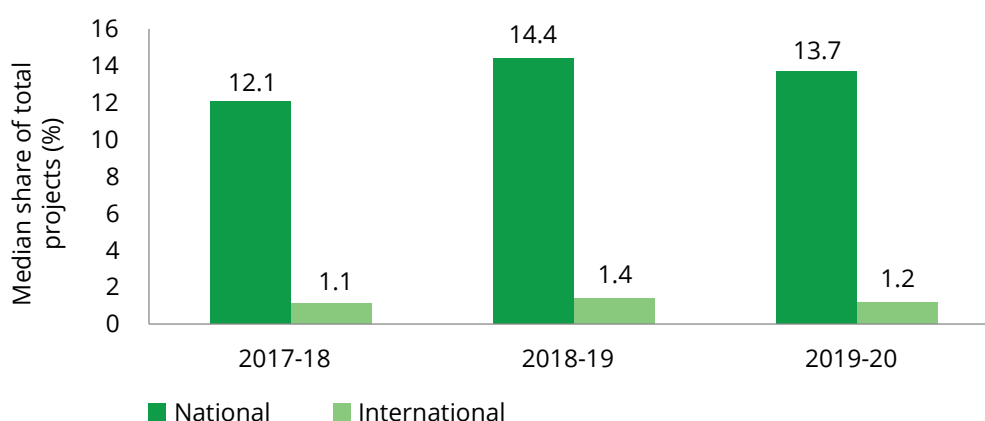
5.2.2 Total publication output increasing but share in top 10 percent journals declining

The total publication output was 16,202 in 2019 compared to 15,778 in 2017. Over 95 percent of these publications were identified as being published in peer-reviewed journals. The contribution of the 193 labs to India's publication output would be around 15 percent.[3] Based on available data for around 161 labs, the median value for the share of publications in the top 10 percent journals has seen a drop from around 6.5 percent in 2017 to 5.4 percent in 2019.

As seen above, the 193 labs account for close to 11 percent of national R&D spending, whereas the higher education sector accounts for around 7 percent of national R&D spending. While some labs do stand out in terms of publications in peer-reviewed journals, it would appear the focus of the public R&D institutions is clearly not oriented towards the traditional metrics of scientific excellence such as publishing in high quality peer-reviewed journals.

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[3]*Estimates based on India's total publication output between 2015 and 2019, CTIER Handbook 2021.*

Figure 5.20 Total number publications
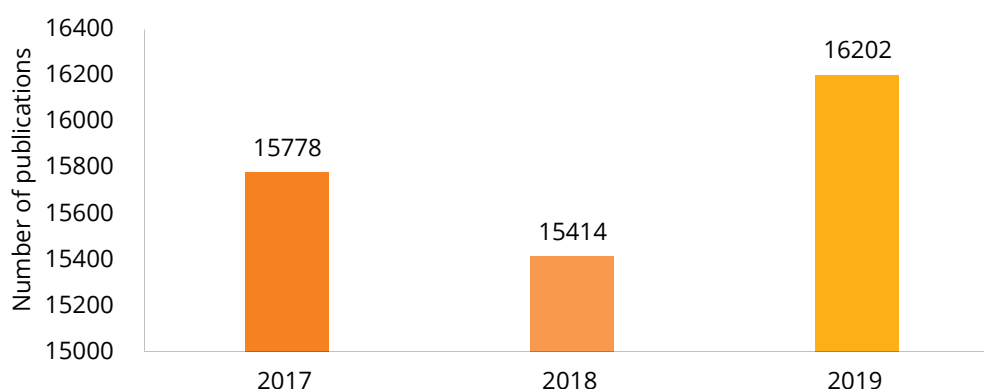
Figure 5.21 Share of publications in top 10 percent of journals is declining
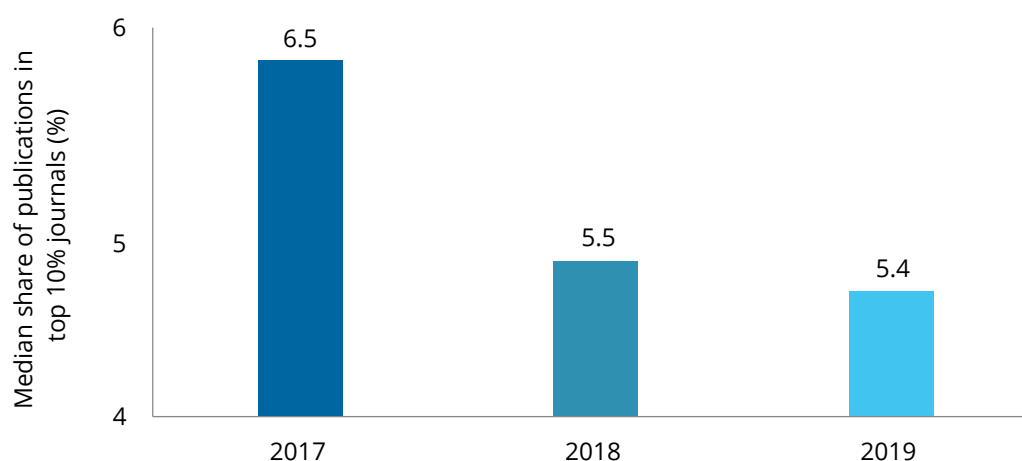
With respect to collaborations on publications, the median value for share of collaborations in publications has seen a steady increase over the three years especially for national collaborations. The share of international collaborations in publications appears to have remained steady over the three year period.

Figure 5.22 Publication collaborations: International and National (%)
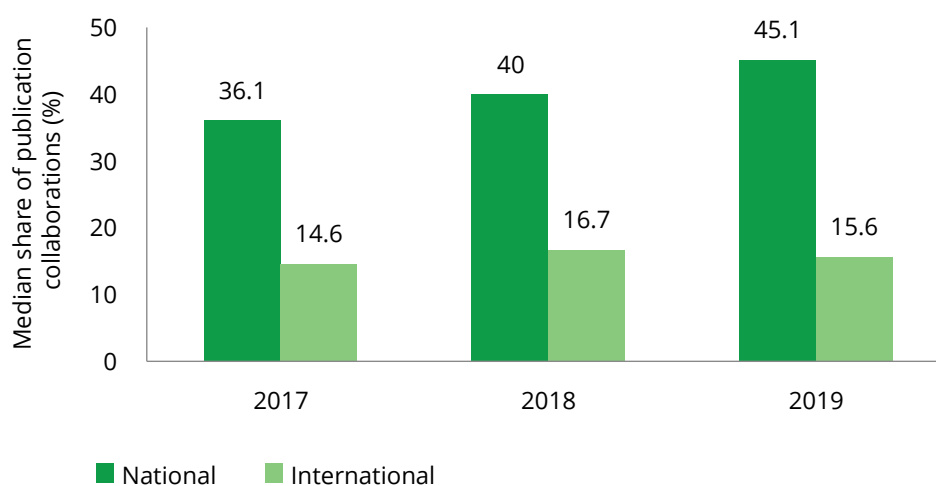
5.2.3 Patent filings and grants have slowed compared to 2017-18

The patent filings have slowed from 657 in 2017-18 to around 605 in 2019-20. The patents filed for by the 193 labs account for around 2 percent of the total patents filed within India and outside India by Indian residents.[4] In Figure 5.23, it is interesting to note that both plant variety and design filings have seen an increase in 2018-19 as well as 2019-20, whereas some of the other IPR saw a dip in filings in 2018-19 before picking up again in 2019-20.

Figure 5.23 Patent filings have slowed over the years
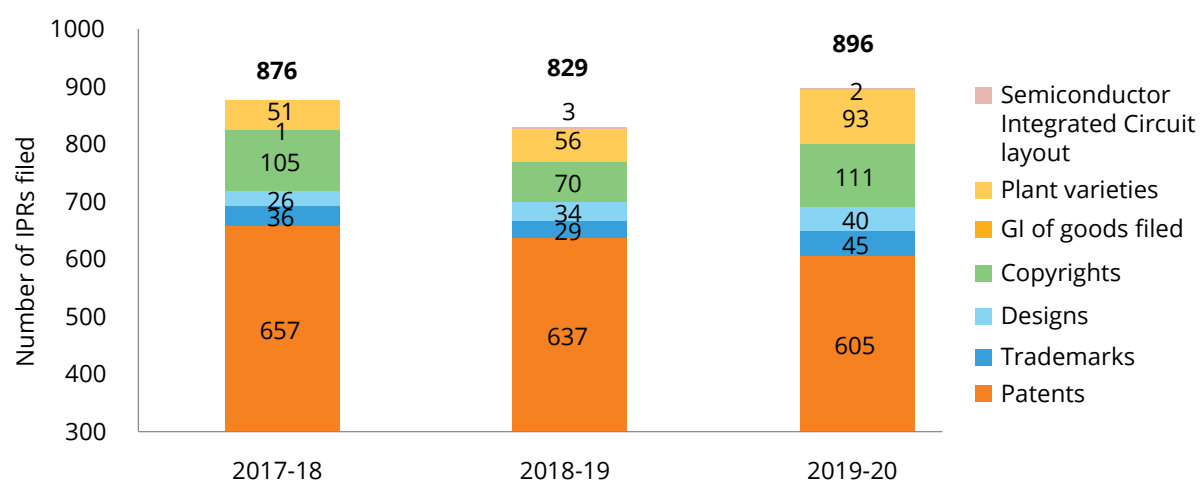
In terms of patents granted, the 193 labs accounted for around 8 percent of the total patents granted within India and outside India to residents in India.[5] For the other IPR, while plant varieties, designs and copyrights have seen an increase in 2019-20 compared to their 2017-18 levels, the number of trademarks obtained by the labs has seen a decline over the same period.

Figure 5.24 Trends of IPR grants

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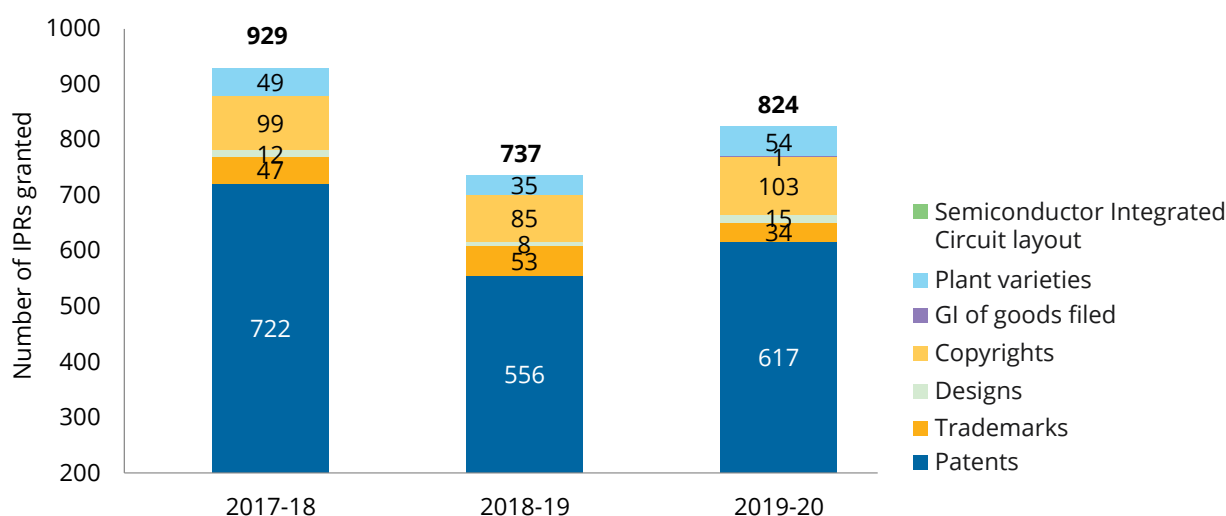
[4]Number of patents filed within India and outside India by Indian residents based on estimates in CTIER Handbook 2021 and World Intellectual Property Organization (WIPO)

[5]Number of patents granted within India and outside India to residents in India. based on estimates in CTIER Handbook 2021 and World Intellectual Property Organization (WIPO)

5.2.4 Technologies benefiting the domestic economy

The number of technologies being transfered are targeted largely at the domestic economy as highlighted earlier, providing wide ranging solutions to a number of challenges the domestic economy is facing. There has been a gradual decline in the total number of technologies transferred each year, although the increase in the international technology transfer should be viewed positively. Labs should be encouraged to participate in greater international project collaborations as well as offer home grown solutions to global challenges on climate and health for example through greater technology transfers.

Figure 5.25 Technology transfer is targeted largely at the domestic economy
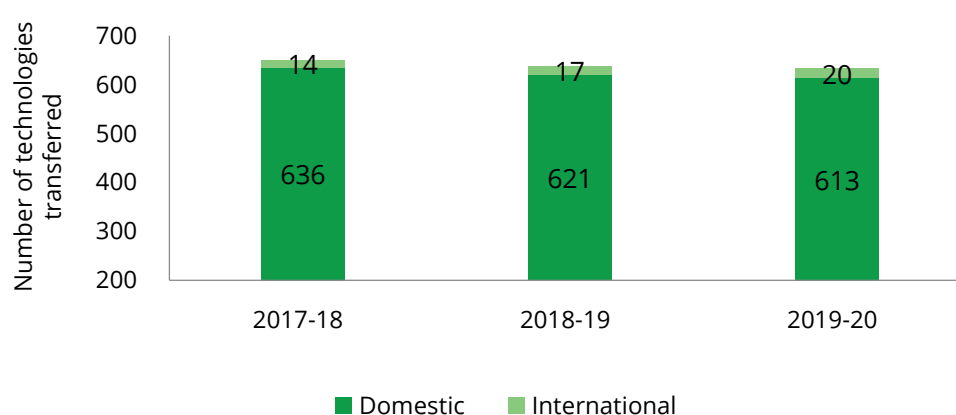
5.2.5 New products and services introduced

A total of 1513 new products and 1480 new services were introduced in the period under consideration. Of the 193 labs, there were 46 labs that did not introduce a single new product or service in any of the three years.

Figure 5.26 - New products and new services introduced (In Numbers)
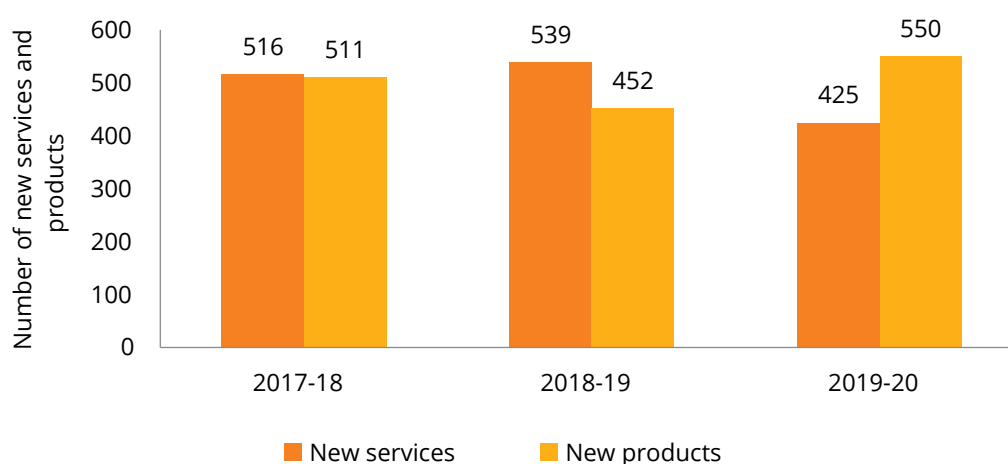
5.2.6 Total earnings and extramural funding

The labs earned over Rs 5300 Cr over the three year period, with the main contribution coming from earnings through consultancy fees. The earnings through consultancy fees through non-government is however driven by a small number of labs that are also engaged in providing services to specific sectors like manufacturing, infrastructure and healthcare whereas the government consultancy earnings are driven by sectors such as electronics and infrastructure among others. It is encouraging to note that fees earned through training have also been increasing both from government and especially non-government sources. There has been some slowdown in earnings of commercialisation from non-government sources.

Figure 5.27 Earnings from government and non-government sources: Main source of earnings is consultancy fees
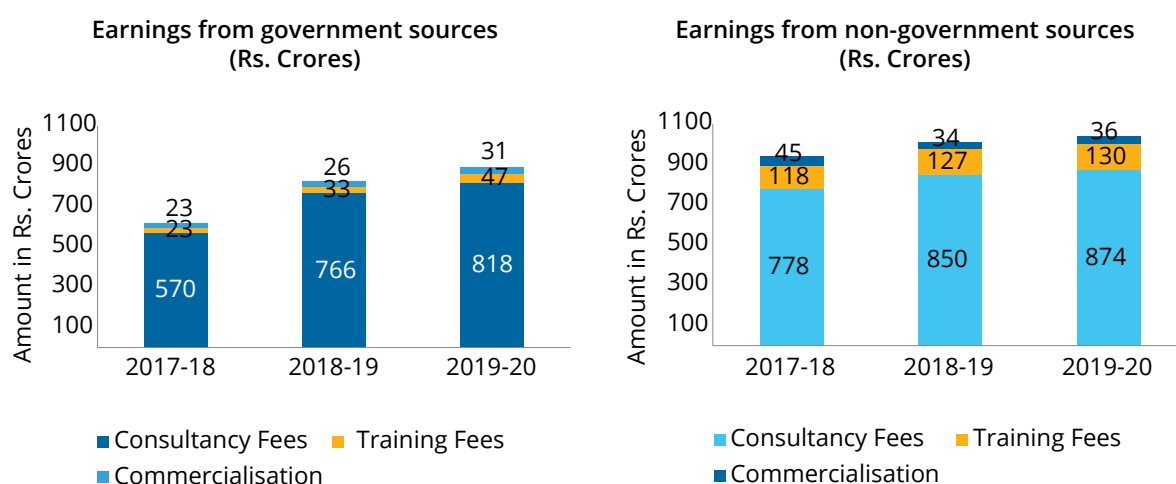
With respect to extramural funding, over 90 percent of the funding is coming from other government sources.

Figure 5.28 Extramural funding largely from other government sources
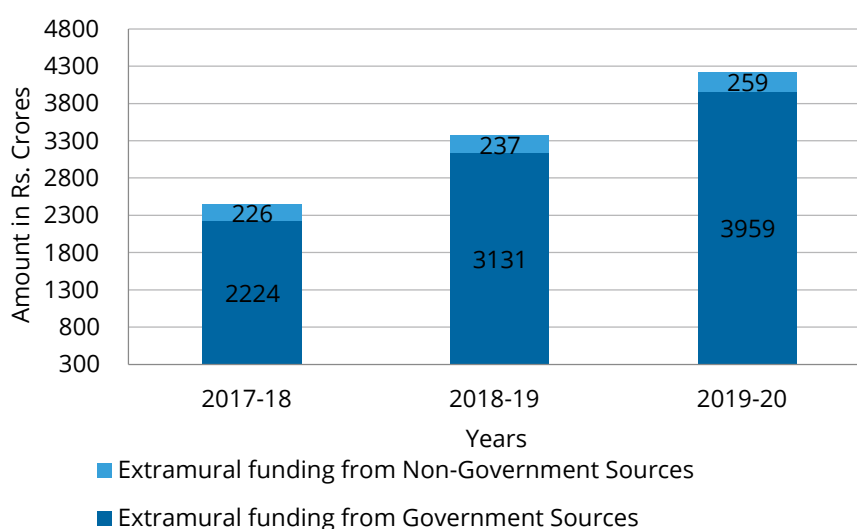
5.3 Contributions of Labs to socio-economic development

5.3.1 Technologies developed targeting SDGs and national programmes

The total number of technologies that were being or had been developed with TRLs 0 to 4 and targeting SDGs and national programmes were 666 in 2019-20 compared to 597 in 2017-18. This compares to 1192 technologies that were developed or were being developed with TRLs 5 and higher targeting SDGs and national programmes in 2019-20 versus 1088 technologies in 2017-18.

Figure 5.29 Total number of technologies targeting SDGs and National Programmes

Technologies (TRL 0-4) targeted towards SDGs

Technologies (TRL 5 and higher) targeted towards SDGs
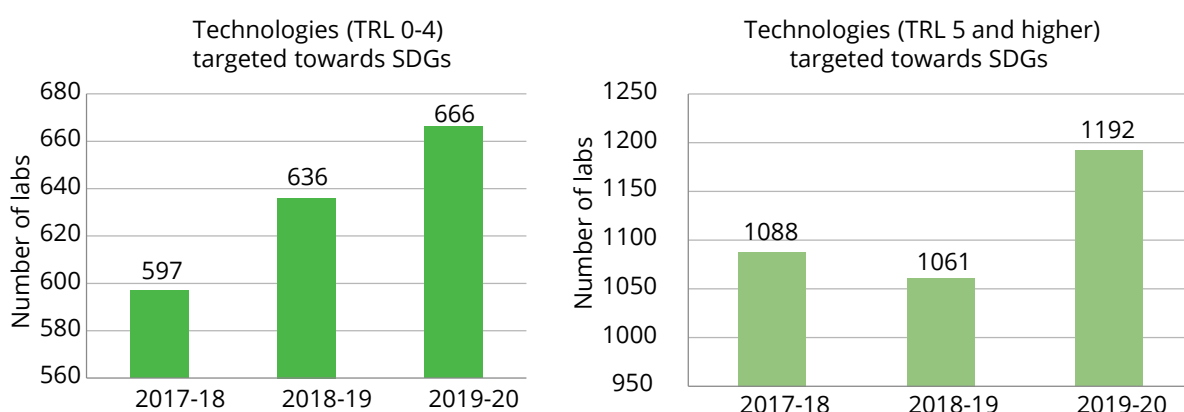
The tables below showcase the most commonly targeted SDGs and National programmes. Around 60 percent of labs through their technologies targeted SDG goal 1 'No poverty' and SDG goal 3 'Good health and well-being'. The same technologies may have also targeted multiple other SDGs and national programmes. Going forward, it would be important for technologies to also increasingly target other SDGs as well, for example 'Clean water and sanitation' , 'Affordable and clean energy' and 'Climate action'.

Table 5.4 Mostly commonly targeted SDGs are No poverty and Good health and well-being

Sustainable development goals (SDGs)		Number of labs
Goal 1	No poverty Goal	116
Goal 2	Zero hunger Goal	57
Goal 3	Good health and well-being Goal	115
Goal 4	Quality education Goal	34
Goal 5	Gender equality Goal	24
Goal 6	Clean water and sanitation Goal	38
Goal 7	Affordable and clean energy Goal	28
Goal 8	Decent work and economic growth Goal	47
Goal 9	Industry, innovation and infrastructure Goal	80

Sustainable development goals (SDGs)		Number of labs
Goal 10	Reduced inequalities Goal	19
Goal 11	Sustainable cities and communities Goal	35
Goal 12	Responsible consumption and production Goal	43
Goal 13	Climate action Goal	53
Goal 14	Life Below Water Goal	17
Goal 15	Life on land Goal	30
Goal 16	Peace, justice and strong institutions	4
Goal 17	Partnerships for the goals	27

The most common category of national programmes chosen by the labs was 'Other'. The 'Other' category was meant to allow labs to highlight national programmes not mentioned in the list below and possibly very specific to individual scientific agencies or central government ministries. Besides the 'Other' category, around 40 percent of labs said they targeted national programmes like the Skill India Mission' and 'Make in India'.

Table 5.5 Mostly commonly targeted SDGs are No poverty and Good health and well-being

National programmes		Number of labs
NP1	National Health Protection Scheme	40
NP2	Mid-day Meal Programme	12
NP3	Swachh Bharat Mission	55
NP4	'Housing for All by 2022' Mission	3
NP5	National Rural Drinking Water Programme	14
NP6	Jan Dhan Yojna	1
NP7	Skill India Mission	72
NP8	Make In India	81
NP9	Shramew Jayate Yojna	1
NP10	National Ayush Mission (NAM)	14
NP11	Hriday Scheme	2
NP12	Ujala Yojna	4
NP13	Atal Pension Yojna	1
NP14	Pradhan Mantri Swasthya Suraksha Yojana (PMSSY)	6

National programmes		Number of labs
NP15	Smart Cities Mission	20
NP16	AMRUT	4
NP17	UDAY	1
NP18	Start Up India	44
NP19	Gramoday se Bharat Uday	17
NP20	Pradhan Mantri Ujjwala Yojana (PMUY)	2
NP21	Namami Gange	8
NP22	National Super Computing Mission	4
NP23	National Inter Disciplinary Cyber Physical Systems	**3**
NP24	Other	**103**

5.3.2 Target beneficiaries of labs programmes

The primary beneficiaries of the programmes of the 193 labs are government departments followed by individuals. A high share of labs also target industry, although this may not be very evident judging by the low collaborations with industry on projects. Quite possibly the main connection with industry for a number of labs may be through activities like consultancy and training.

Figure 5.30 Government departments are main beneficiaries followed by individuals
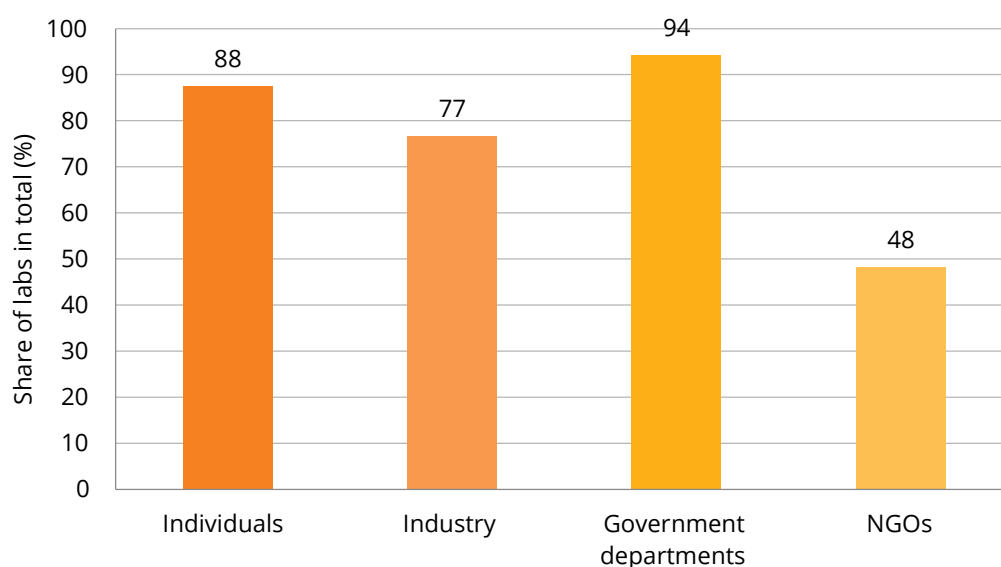
5.3.3 Supporting entrepreneurship through training

The number of beneficiaries from the skill development, entrepreneurship and innovation trainings organised by the labs have increased over the three years. In 2019-20 there were

197,003 individuals who benefited from these training programmes compared to 156,289 in 2017-18. Although difficult to quantify, it appears that labs may be contributing much to employment generation through these training programmes than through the startup route. Very few labs are currently engaged in incubation activities or actively engaged with the startup ecosystem. In 2019-20 there were just 35 labs that were providing incubation support to startups as can be seen in Figure 5.32.

Figure 5.31 Skill development, entrepreneurship and innovation trainings
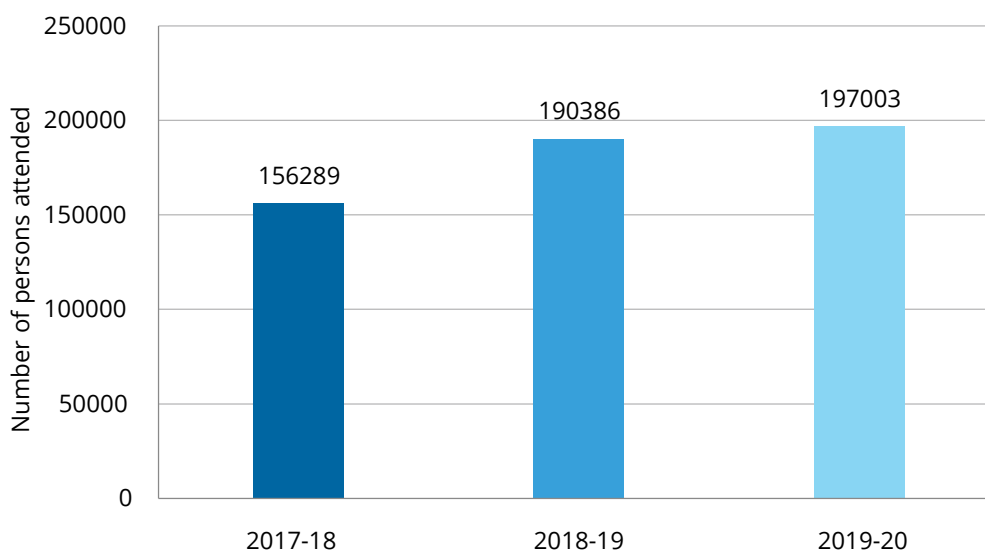
Figure 5.32 Number of labs incubating startups
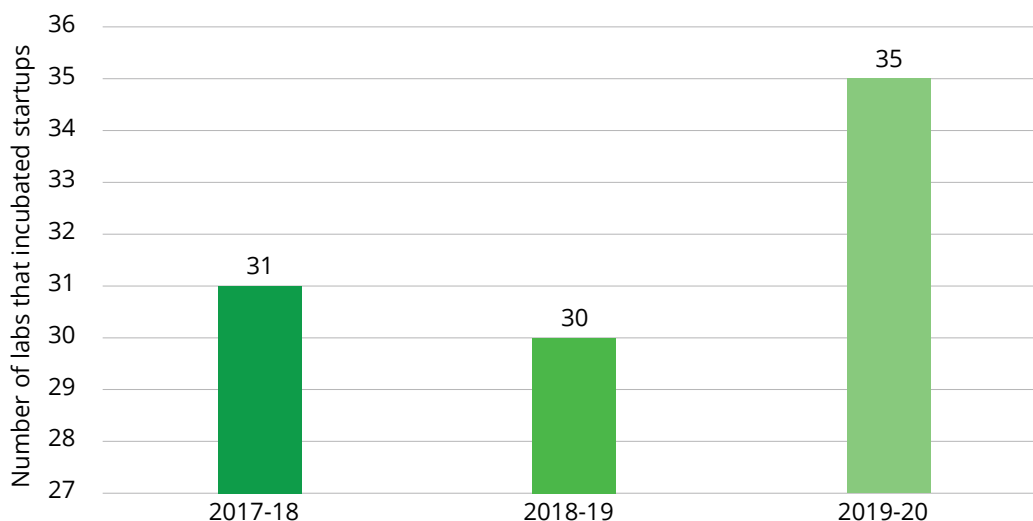
5.3.4 International and national programmes organised

Of the total number of programmes organised over the three years under consideration, just 6 percent of the programmes were international S&T programmes or conferences. By definition, an international programme or conference required 5 international speakers and a minimum attendance of 100 participants, whereas a national programme required a minimum attendance of 50 participants. The number of national programmes organised saw an increase from 2628 in 2017-18 to 2828 in 2019-20. The period was of course pre-pandemic and with the increased use of digital platforms for hosting conferences since the start of the

pandemic, the share of international programmes in total programmes should see an increase going forward.

Figure 5.33 Significantly larger share of national conferences organised
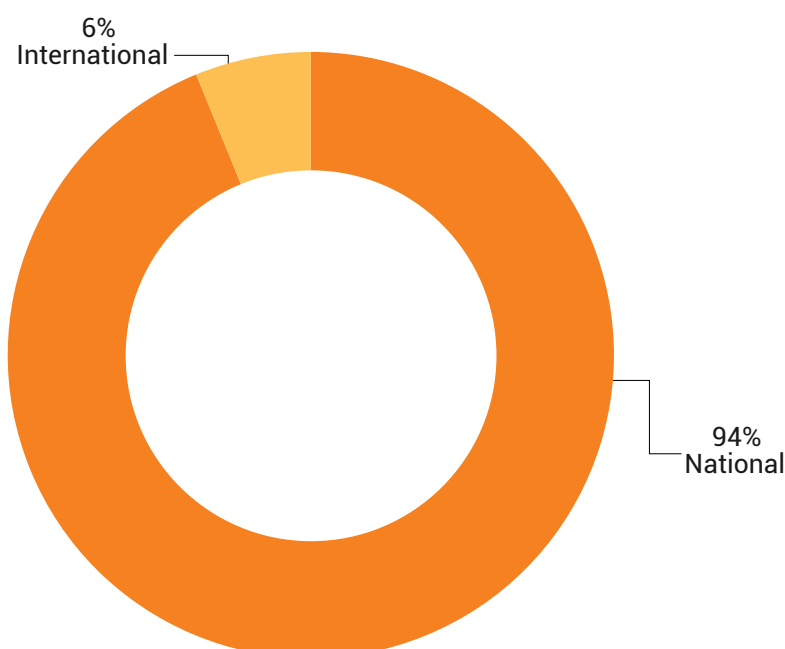
Figure 5.34 Number of national conferences organised
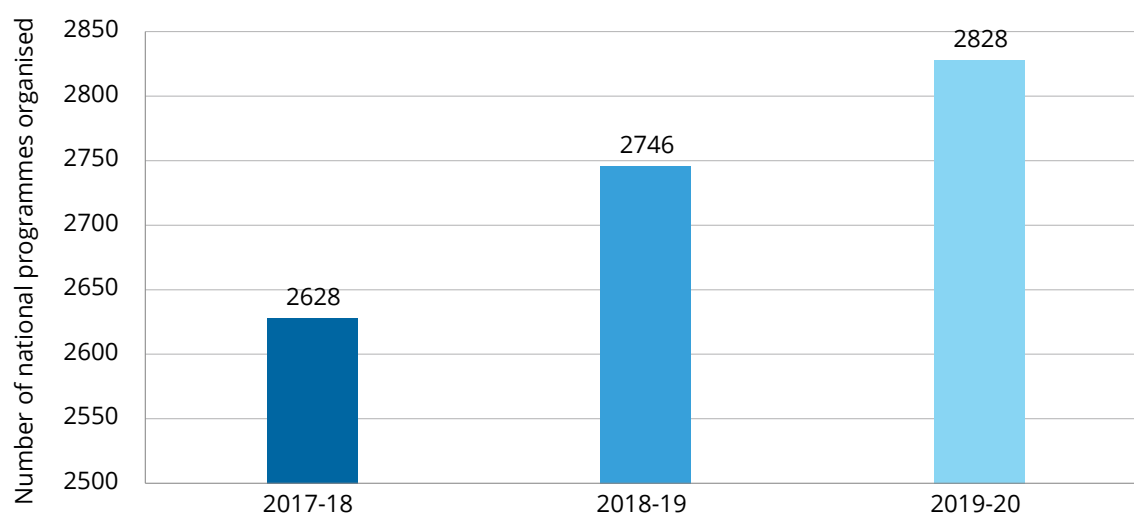
5.3.5 Other activities - outreach and contribution to policy

The number of outreach activities conducted across the country to promote S&T including in schools and colleges was 37,413 in 2019-20 compared to 15,978 activities in 2017-18. There were very few labs that did not conduct any outreach activities in each of the three years. When it came to contributions to national policy, it was found that 50 percent of labs have contributed towards national policies, regulations or standards, either through their staff

being part of various committees or their work having contributed to a policy or regulation etc. There were 17 percent of the labs that contributed to international policies, regulations and standards. Given the wide ranging scope of work and contributions highlighted earlier in the chapter, promoting the activities and contributions of the various labs may draw many more labs into contributing to policy formulations related to global challenges.

Figure 5.35 Outreach activities conducted for promotion of S&T
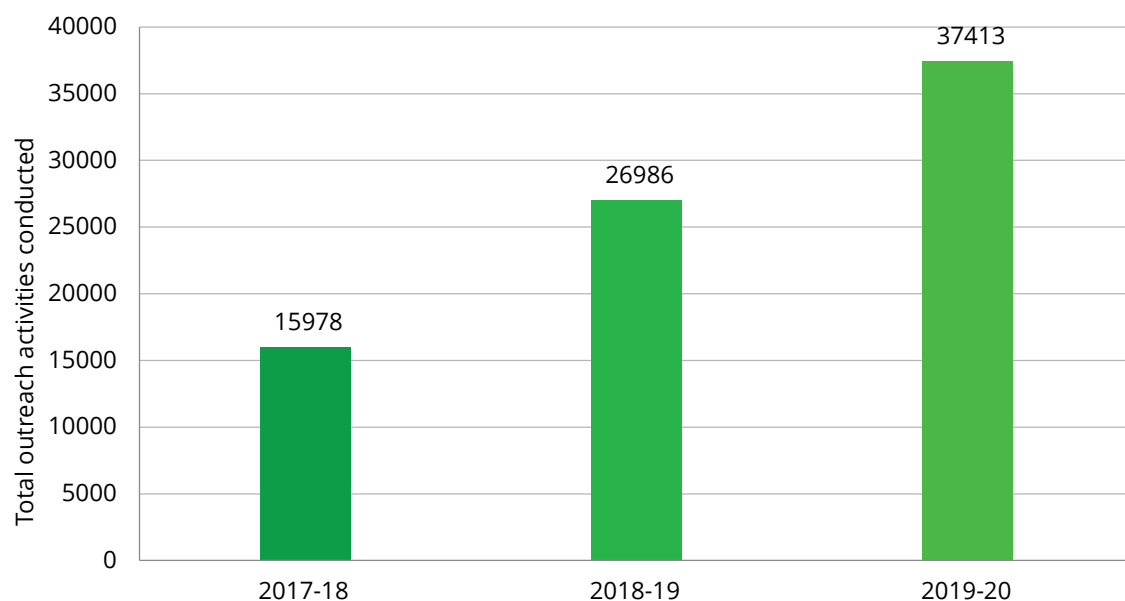
Figure 5.36 Contributions to policies, regulations and standards
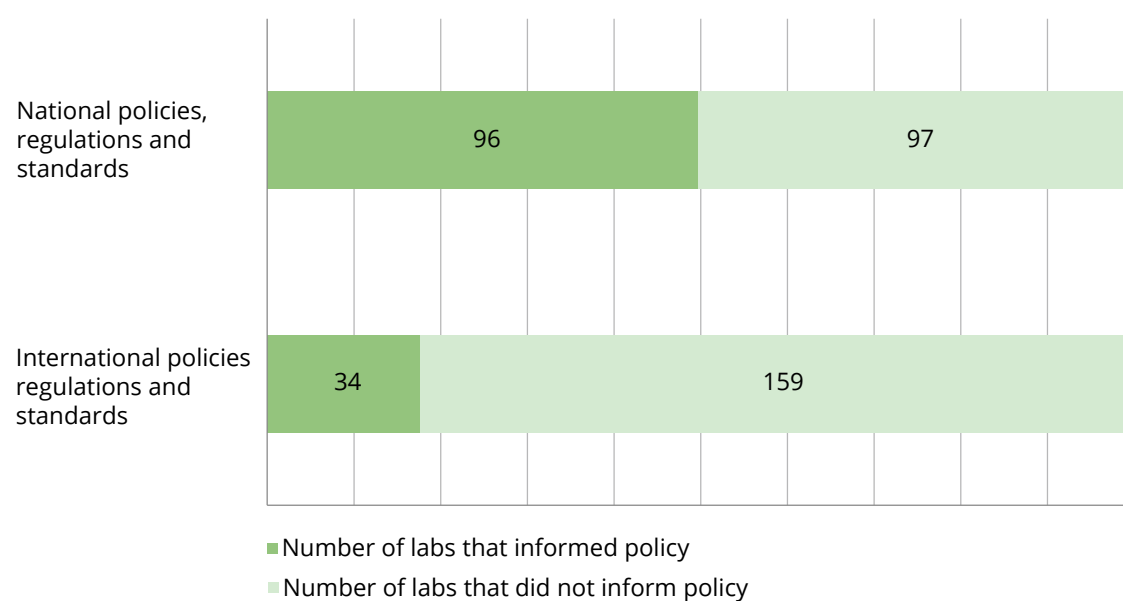
Key takeaways:

Institutional capabilities and practices	01

- The average over three years of the total budget for the 193 labs participating in the study was around Rs 12,914 Cr. The labs covered in this study roughly account for over 45 percent of the spending by key scientific agencies (excluding Strategic R&D labs) and other central government departments, and around 11 percent of national R&D.

- The R&D and S&T expenditure as a share of the budgets of the labs has a median value that ranges between 37 percent and 39 percent over the three years.

- The median value for the share of scientists in overall staff increased to 54.1 percent in 2019-20 from 51.6 percent in 2017-18 on the back of increased contractual research staff.

- The median value for the share of women researchers in scientific staff for the labs remains low at 30 percent in 2019-20. Every effort should be made to increase the participation of women in the STEM workforce.

- For young researchers as a share of the scientific staff, the median value has remained steady between 63 to 65 percent over the three year period. Young researchers here by definition are below the age of 40.

- The number of outside researchers supported by the labs increased over the period under consideration. This trend is an encouraging one and possibly driven more by researchers from other labs or academic institutions compared to researchers from industry.

- In terms of policies and guidelines, labs are adhering to most of the best practices outlined in the framework. One area of improvement that around 40 percent of the labs would need to consider is in deploying a software system to track and manage their projects from conception to completion.

- At present only 35 percent of the labs said they had an EDI cell. Around 90 percent of labs have made provisions for differently abled facilities.

- Around 95 percent of labs said they had incentives in place to promote talent while around 98 percent of labs had a structured career progression plan in place for their scientific staff.

- The spending on training of their staff remains close to or less than 1 percent of the total budget for most labs. The spending on training of staff by the labs has been gradually increasing in the three years under consideration. This should continue and with a higher share of the budget possibly being allocated towards the continuous skills upgradation of the staff to keep up with the rapidly evolving technology changes globally.

Scientific output and innovation outcomes of the labs   02

- Between 2017-18 and 2019-20, the total number of projects being undertaken by the 193 labs increased from 11,500 to around 12,900. Only 37 percent of labs were engaged in collaborations with industry in India, and around 8 percent of labs were collaborating with industry overseas.

- Total publication output was 16,202 in 2019-20 compared to 15,778 in 2017-18. Over 80 percent of these publications were identified as being published in peer-reviewed journals. The contribution of the 193 labs to India's publication output is estimated to be around 15 percent.

- The patent filings have slowed from 657 in 2017-18 to around 605 in 2019-20. The patents filed for by the 193 labs account for around 2 percent of the total patents filed within India and outside India by Indian residents. Plant variety and design filings have seen an increase in 2018-19 as well as 2019-20

- For patents granted, the 193 labs accounted for around 8 percent of the total patents granted within India and outside India to residents in India. For the other IPR, while plant varieties, designs and copyrights have seen an increase in 2019-20 compared to their 2017-18 levels, the number of trademarks obtained by the labs has seen a decline.

- The number of technologies being transferred are targeted largely at the domestic economy. There has been a gradual decline in the total number of technologies transferred each year from 650 in 2017-18 to 633 in 2019-20. There has however been an increase in the international technology transfer over this same period.

- A total of 1513 new products and 1480 new services were introduced in the period under consideration. There were 46 labs that did not introduce a single new product or service in any of the three years.

- The labs earned Rs 5300 Cr over the three year period, with the main contribution coming from earnings through consultancy fees. The earnings through consultancy fees is however driven by a small number of labs that are also engaged in providing services to specific sectors like manufacturing, infrastructure, electronics and healthcare.

Contributions of Labs to socio-economic development   03

- The labs being covered in this study are impacting the wider economy in a variety of ways. Some broad overlapping themes cover various aspects such as healthcare, agriculture, energy and environment, transport and infrastructure, livestock and industries like food processing, textiles etc.

- The labs are a repository of knowledge and are playing an important role in addressing a number of societal and developmental challenges.

- There were 666 technologies with TRL levels between 0-4 and 1192 technologies with TRL levels 5 and higher (targeting SDGs and national programmes) that were being developed in 2019-20.

- Around 60 percent of labs through their technologies targeted SDG goal 1 'No poverty' and SDG goal 3 'Good health and well-being'. The most common category of national programmes chosen by the labs was 'Other'. The 'Other' category was meant to allow labs to highlight national programmes not mentioned in the list provided and that were possibly very specific to individual scientific agencies or central government ministries.

- In 2019-20 there were 197,003 individuals who benefited from these training programmes compared to 156,289 in 2017-18. Very few labs are currently engaged in incubation activities or actively engaged with the startup ecosystem. In 2019-20 there were just 35 labs that were providing incubation support to startups.

- Of the total number of programmes organised over the three years under consideration, just 6 percent of the programmes were international S&T programmes or conferences. The number of national programmes organised saw an increase from 2628 in 2017-18 to 2828 in 2019-20.

- The number of outreach activities conducted across the country to promote S&T including in schools and colleges was 37,413 in 2019-20 compared to 15,978 activities in 2017-18. There were very few labs that did not conduct any outreach activities in each of the three years.

- 50 percent of labs have contributed towards national policies, regulations or standards, either through their staff being part of various committees or their work having contributed to a policy or regulation etc. There were 17 percent of the labs that also contributed to international policies, regulations and standards.

Chapter 6
BASIC R&D LABS

Basic research by definition is experimental or theoretical work that is undertaken primarily to acquire new frontiers of knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. The TRL levels of the technologies developed by these laboratories were between 0 and 4. The present chapter analyses the responses of 90 laboratories that chose to categorise themselves under Basic R&D labs.

There were 90 labs that categorised themselves as Basic R&D labs, of which there were 45 labs that were undertaking pure basic R&D while the remaining 45 were hybrid in nature signifying that they were also undertaking applied research and/or services R&D.

Laboratories from CSIR and ICAR accounted for nearly 50 percent of the 90 R&D labs (pure basic + hybrid basic). When one considers the sample of R&D labs that were only engaged in basic R&D, the largest numbers of labs came from DST, followed by ICAR, ICMR and DBT.

The average budget for the overall sample of 90 basic research labs was around Rs.71 crores, while it was around Rs.80 crores for the 45 labs that were engaged in only basic R&D. With respect to scientific staff, the average number of scientific staff per laboratory for the overall sample of 90 labs was around 145, with this number dropping to around 125 scientific staff per laboratory for the labs engaged in only basic R&D. There is a significant variation in terms of budgetary outlay as well as by the number of scientific staff across the category of Basic R&D labs. There were around 4 or 5 labs that reported a high number of project based research staff, which contributed to the variation in the numbers of total scientific staff reported by these 90 labs. The labs with a high number of project based research staff included labs from key scientific ministries as well as the institutions engaged in educational activities.

Évaluation of Innovation Excellence Indicators | Volume-I

Figure 6.1 Sub-pillar wise average scores for Basic R&D Labs
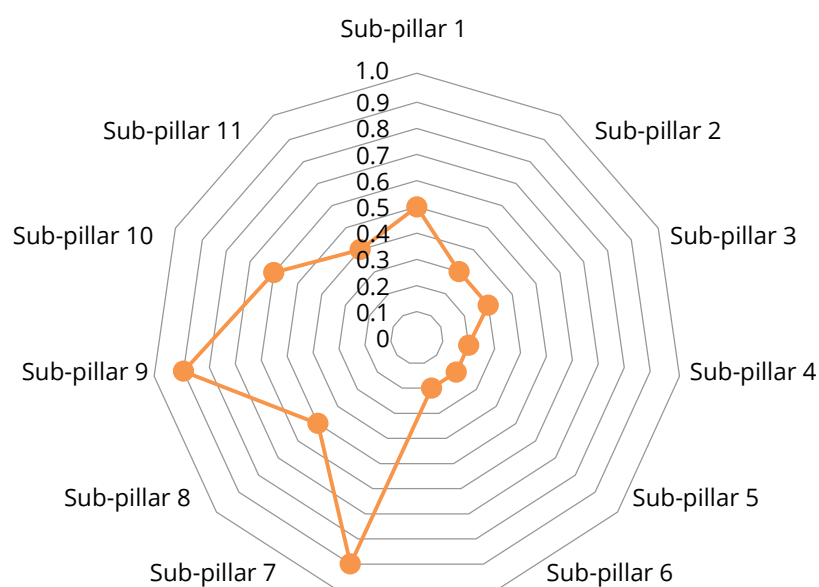
> Figure 6.1 captures the average scores of the labs on the various sub-pillars. Most labs in this exercise have exhibited relative weakness in the sub-pillars that fall under the Socio-economic Impact and STI Excellence pillars compared to the Organisational Effectiveness pillar.

S.No.	Sub Pillar Name	Pillar Name
1	Contribution to SDGs and national programmes	Socio-economic impact
2	Employment generation and human resource development	
3	Scholarly research, development output and quality	Science, technology and innovation excellence
4	Development and innovation output and quality	
5	commercialisation of technologies and revenue generation	
6	Collaborative research	Organisational effectiveness
7	Mandate alignment	
8	Resource management	
9	Governance	
10	Equity, diversity, and inclusion	
11	Internal capacity building	

As can be seen in Figure 6.1, the labs have performed relatively better in sub-pillar 1 and sub-pillars 7 to 11 compared to sub-pillars 2 to 6. The sub-pillars 2 to 6 cut across the Socio-economic impact pillar and the STI excellence pillar.

Figure 6.2 Pillar wise scores for Basic R&D Labs
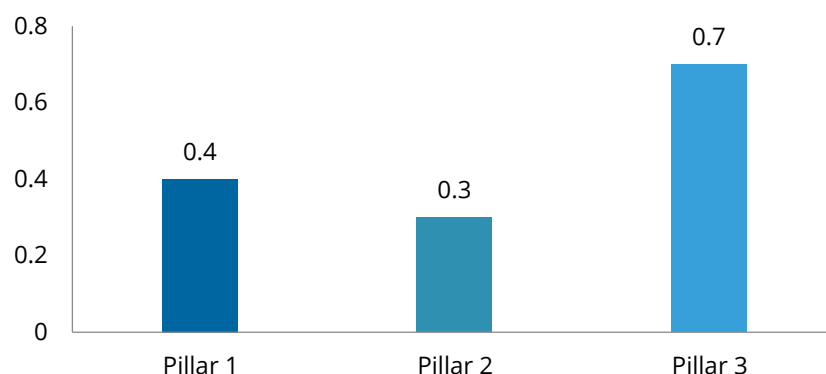
Figure 6.2 captures the pillar-wise average scores for the Basic R&D labs. The organisational effectiveness pillar has garnered the highest average score amongst all the pillars.

The performance of the basic labs on each of the pillars suggests that there are certain areas the labs could perhaps focus on going forward. Some examples of these areas include increasing their IPR output or even improving the collaborative nature of their research especially on projects with industry. Increased collaborations could potentially also be an additional source of revenue generation or non-government extramural funding for the basic labs. Even where the labs have tended to perform relatively better compared to indicators in sub-pillars 2 to 6, for example on indicators related to equity, diversity and inclusion or 'capacity building', there is significant scope for a number of labs to improve the participation of women researchers in the workforce or increase the amount of expenditure allocated towards training of their research staff.

The following section considers the performance of the labs focusing on around 40 key indicators that drive the performance in the various sub-pillars mentioned in Figure 6.1, and thereby the overall pillar. In terms of weights attached to the indicators, these 40 indicators account for around 80 percent of the total framework. For comparability, the data where necessary has been scaled by either per 100 scientific staff or per Rs.10 Cr of budgetary support.

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Pillar 1: Socio-economic Impact

</div>

The indicators in the pillar on socio-economic impact that have been captured below include the number of technologies (with TRL levels between 0 and 4) targeted towards SDGs or national programmes, the number of projects being undertaken by the labs, the targeted beneficiaries of the labs programmes, number of degrees (PhDs, master's, undergraduate) awarded and the number of interns trained at the labs. The data presented in the charts below are based on an average of the three years under consideration, namely FY2018, FY2019 and FY2020.

- The data shows that a majority of the labs are developing up to 10 technologies (targeting SDGs and/or national programmes) per hundred scientific staff. There were 11 labs that had developed more than 15 technologies per 100 scientific staff.

- Over 33 percent of the labs are engaged in more than 60 projects per hundred scientific staff. There were 17 labs that had undertaken more than 90 projects per 100 scientific staff.

- The primary beneficiaries of the output from the basic labs are government departments followed by individuals.

- Close to 50 percent of the labs award less than 10 educational degrees (combined PhDs, Master's and undergraduate degrees).

- More than 60 percent of the labs train up to 60 interns each year per hundred scientific staff.

Sub-pillar 1: Contribution to SDGs and national programmes

Figure 6.3 Technologies targeted towards SDGs & National Programmes
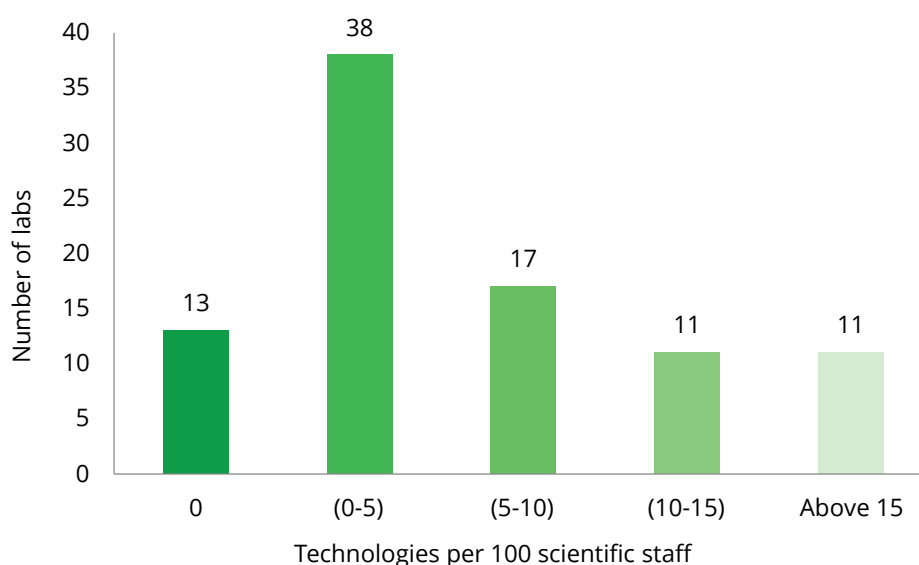
There were 13 labs that did not report any technologies with TRL between 0 and 4 that had been developed during the period under consideration, while 22 labs reported having developed more than 10 technologies per 100 scientific staff. Over 40 percent of the labs had developed upto 5 technologies per 100 scientific staff. Given that around 45 basic R&D labs were hybrid, it is likely that many of them may have also developed technologies with TRL 5 and above, which would not be reflected here.

The 22 labs that had developed more than 10 technologies per 100 scientific staff included 7 labs from ICAR, 3 labs from ICMR, 2 labs from CSIR and one each from DBT and DST. The remaining labs in this set of 22 were from other central government ministries, and also comprised educational and training institutions.

Of the 90 basic labs, there were 56 labs that were undertaking upto 60 projects per 100 scientific staff. The remaining 34 labs were engaged in more than 60 projects per 100 scientific staff, of which 17 were engaged in more than 90 projects per 100 scientific staff.

Figure 6.4 Project executed per 100 scientific staff
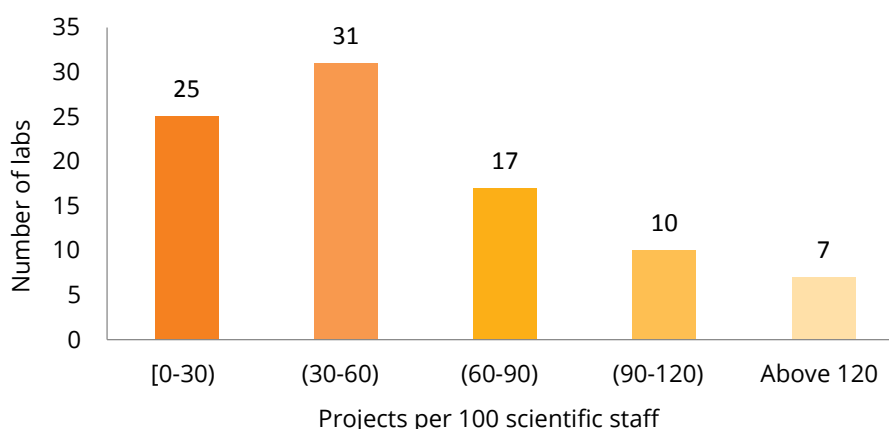
The 17 labs that were engaged in more than 90 projects per 100 scientific staff included 7 labs from ICAR, 2 labs from CSIR, 1 lab from DBT and the remaining 7 labs from other central government ministries. Apart from a few labs that were in common for the most part, the labs that were engaged in higher number of projects per 100 scientific staff differed from those that had developed a higher number of technologies per 100 scientific staff.

Figure 6.5 Beneficiaries of organisation's programmes
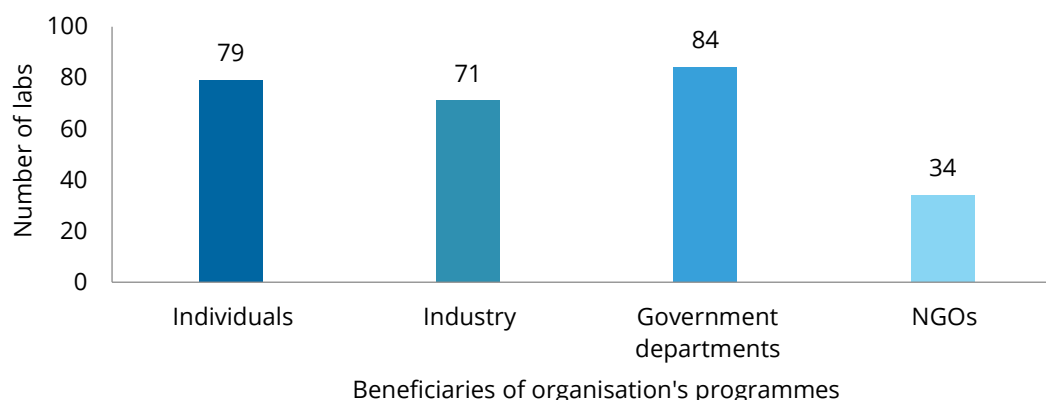
The beneficiaries of each lab's programmes and research were mainly government departments followed by individuals and then industry. Only around 40 percent of the labs had NGOs who were beneficiaries of their programmes.

Sub-pillar 2: Employment generation and human resource development

While this sub-pillar considers the role of labs in incubating startups as well as the employment generated within these start-ups, the engagement with the start-up ecosystem for translational research may seem more applicable to the applied and services labs category and those hybrid labs that are also working on applied research or engaged in services research. However, even basic labs with technologies having TRL between 0-4 should be incentivised to engage more with the start-up ecosystem to become a provider of a wider source of technology for industry.

Figure 6.6 PhD, Masters and Graduate degree awarded per 100 scientific staff

Human resources generated per 100 scientific staff
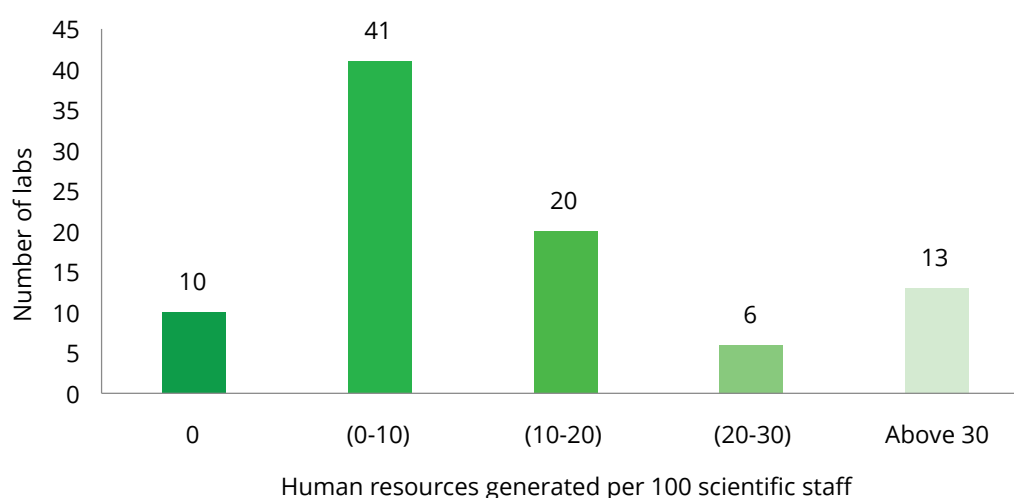
The highest share of labs fall into the bracket of having awarded up to 10 degrees per 100 scientific staff. The degrees awarded are a combination of PhDs, Masters and undergraduate degrees. There were 10 labs that did not award any degrees during the period under consideration, while there were 13 labs that offered more than 30 degrees per 10 scientific staff. These 13 labs comprised 8 labs that were from key scientific ministries while the remaining 5 labs were institutions that also had a focus on education and training. While more than 80 labs out of the 90 did not offer any graduate degrees and 54 labs did not offer any master's degrees, there were only 14 labs that did not offer any PhD degrees. Of the 76 labs that awarded PhD degrees, around 35 percent of the labs mentioned that the PhD dissertations had been reviewed by one or more foreign assessors.
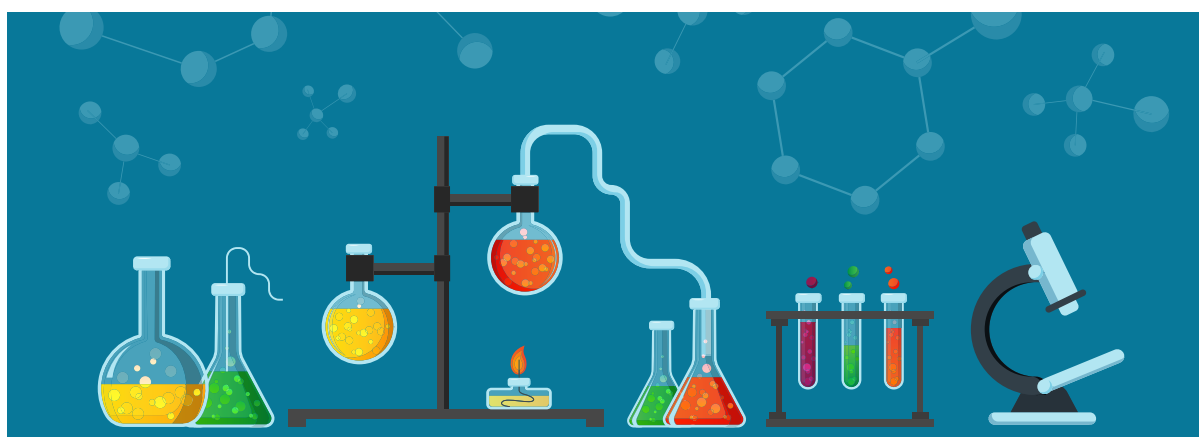
Figure 6.7 Number of interns trained per 100 scientific staff
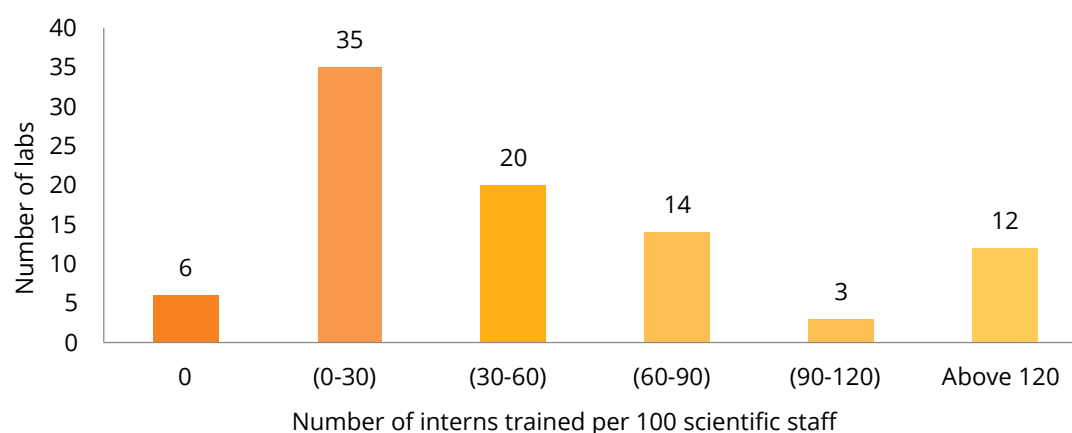
There were 6 labs that did not take on any interns during the periods under consideration. While there were around 55 labs that took on up to 60 interns per 100 scientific staff, there were 29 labs that had more than 60 interns per 100 scientific staff attached to them. There were 12 labs that had more than 120 interns per 100 scientific staff, with 10 labs belonging to key scientific ministries while 2 labs belonged to other central government ministries.

Key takeaways: 01

○ There were 11 labs that had developed more than 15 technologies per 100 scientific staff. For projects executed, 17 labs had undertaken more than 90 projects per 100 scientific staff. However, there was very little overlap between these labs that had developed a higher number of technologies and had undertaken a higher number of projects. The 13 labs that were observed to have not developed any technologies were predominantly from among the major scientific agencies.

○ While the major beneficiaries of the lab's programmes are government departments, the labs may wish to engage with NGOs for greater socio-economic impact.

○ Given the TRL level is between 0-4 for many of the basic labs, the engagement with the start-up ecosystem for translational research may seem more applicable to the applied and services labs category and those hybrid labs that are also working on applied research or engaged in services research. However, even basic labs with technologies having TRL between 0-4 should be incentivised to engage more with the start-up ecosystem to become a provider of a wider source of technology for industry.

○ Close to 50 percent of the labs awarded less than 10 educational degrees. It is understandable that the number of degrees awarded per 100 scientific staff by labs that also focused on education and training were significantly higher than the labs from key scientific ministries. The infrastructure and resources within the

labs of the key scientific ministries should be made more accessible to the higher education system to benefit students pursuing science and engineering degrees.

○ There were around 55 labs that took on up to 60 interns per 100 scientific staff and 6 labs did not train any interns. It is pertinent to mention that labs where possible should look to increase the number of internships provided per year to inculcate 'scientific temper' among the youth of the country.

Pillar 2: Science, technology and innovation excellence

The indicators considered in this pillar pertain to publication output, citations received for the publications, the share of publications in top 10 percent journals, IPR filed, granted and licensed out, new services and/or products introduced, external funding received by the labs and collaborations on projects as well as publications.

○ Around 40 percent of the labs had greater than 60 publications in peer reviewed journals per 100 scientific staff per year. A similar share of labs had over 600 citations per 100 scientific staff with respect to their publications. There were 16 labs that had more than 10 percent of their publications in the top 10 percent journals.

○ A majority of the labs were seen to be engaging in filing patents and a majority were also granted patents, however only around a third of them are seen to be licensing out their patents.

○ Close to thirty percent of the labs did not introduce a single new product or service in the three years under consideration.

○ The main source of external funding for the labs has been government funding, while for nearly two-thirds of the labs the amount received through external funding is less than Rs 2 crores for every Rs 10 crores of their budget spent.

○ Several labs are not collaborating with industry on projects. A majority of labs are engaged in academic international collaborations for up to 20 percent of their projects.

○ For 52 labs, the share of international collaborations in their total publications was up to 25 percent.

Sub-pillar 3: Scholarly research, development output and quality

Figure 6.8 Number of publications per 100 scientific staff
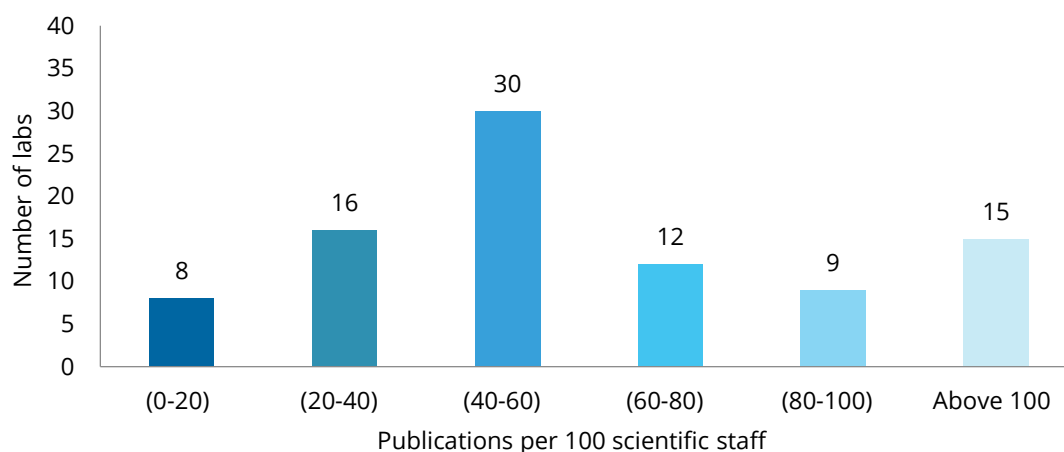
Of the entire sample of basic labs, only two labs did not have any publications in peer reviewed journals. Around 40 percent of the labs had greater than 60 publications per hundred scientific staff. Of the 36 labs that had greater than 60 publications per 100 scientific staff, there were 11 DST labs, 6 ICAR labs, 8 CSIR labs, 3 ICMR labs, 2 DBT labs and 6 labs from other central government ministries. As can be seen from the chart above, there were around 54 labs that had up to 60 publications per hundred scientific staff.

The impact of labs working in healthcare research is visible from the data on publications relative to some of the other fields. Several labs working in critical areas of sustainable agriculture and climate sciences have the potential to increase their reach and impact through wider dissemination and publication in peer reviewed journals, especially their domain knowledge and experience obtained in a developing country context.

Figure 6.9 Number of citations per 100 scientific staff
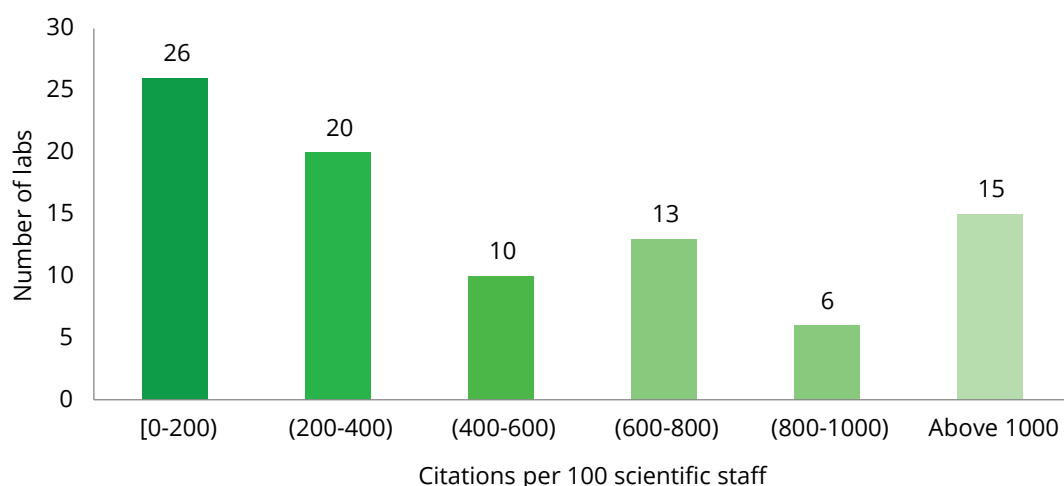
There were around 34 labs on average that received over 600 citations per 100 scientific staff for their respective publications. These 34 labs included 10 CSIR labs, 9 DST labs, 5 DBT labs, 4 ICMR labs, 3 ICAR labs and 3 labs from other central government ministries. Within this set of 34 labs, there were 9 labs that had less than 60 publications. This suggests that despite a lower number of publications these 9 labs had a wider impact in terms of citations per 100 scientific staff.

Figure 6.10 - Share of publications in top 10% of journals
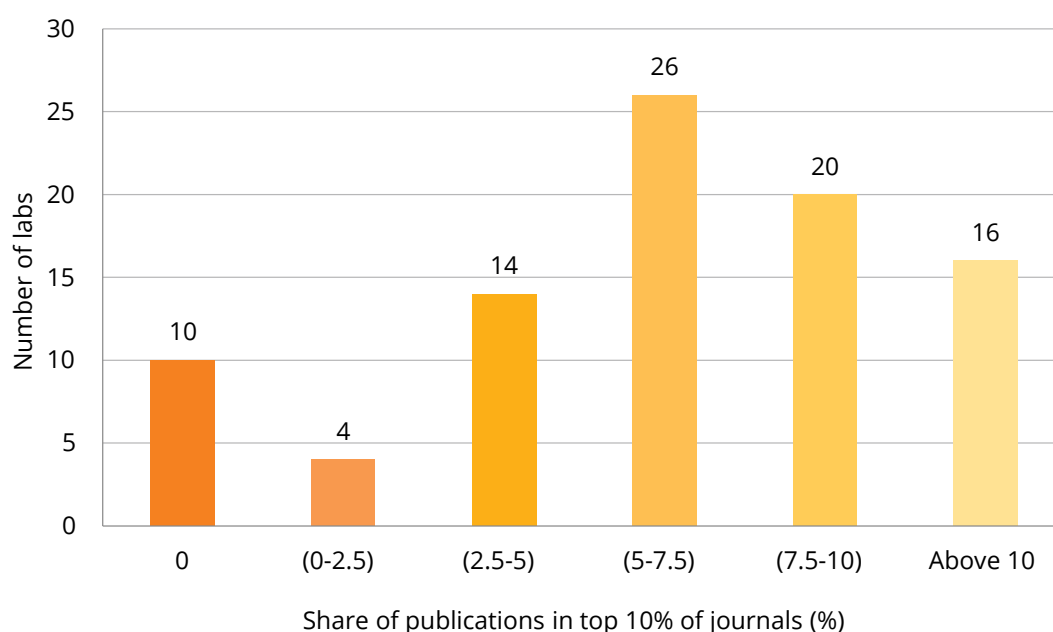
With respect to the share of publications that made it to the top 10 percent of journals, there were just 16 labs that had more than 10 percent of their publications in the top 10 percent journals. In this set of 16 labs, there were 9 labs that had less than 60 publications per 100 scientific staff and 7 labs that had more than 60 publications per 100 scientific staff. It can be seen that again there were a number of labs that may have had fewer publications but a wider impact in terms of their share of publications that made it to the top 10 percent journals. DBT had the highest representation in this set of 16 labs with 5 labs (most of which had less than 60 publications per 100 scientific staff).

Sub-pillar 4: Development and innovation output and quality

Figure 6.11 - Patents filed, granted and licensed out
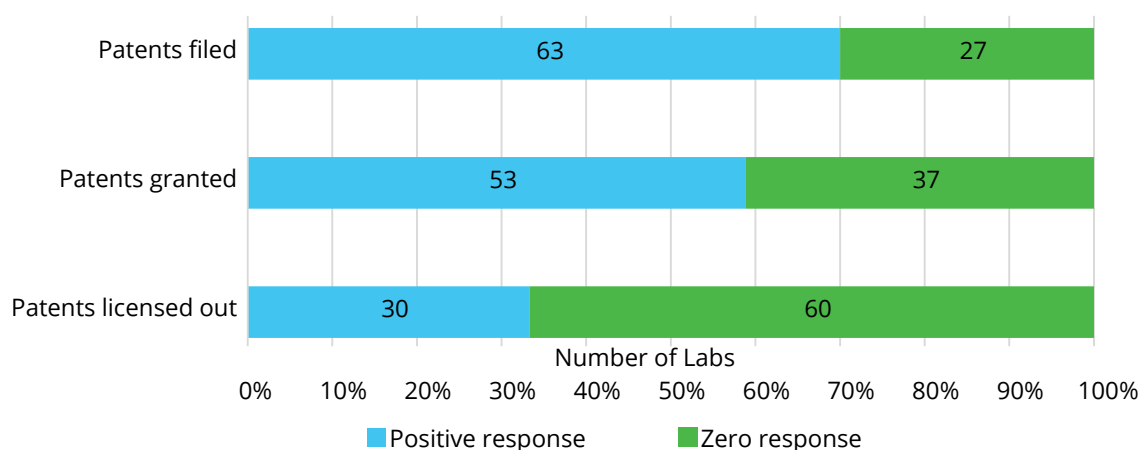
When it came to patents filed and patents granted, the data above shows that 70 percent of the labs filed patents in the period under consideration, while around 60 percent of the labs also obtained patents during this period. However when it came to licensing out patents, the share of labs dropped to a third. Although a large number of labs are filing patents and obtaining patents, the total number of patents filed or granted per 100 scientific staff or even per Rs 10 Cr of budget spent is very low in general.

Figure 6.12 - Intellectual Property Rights filed, granted and licensed out
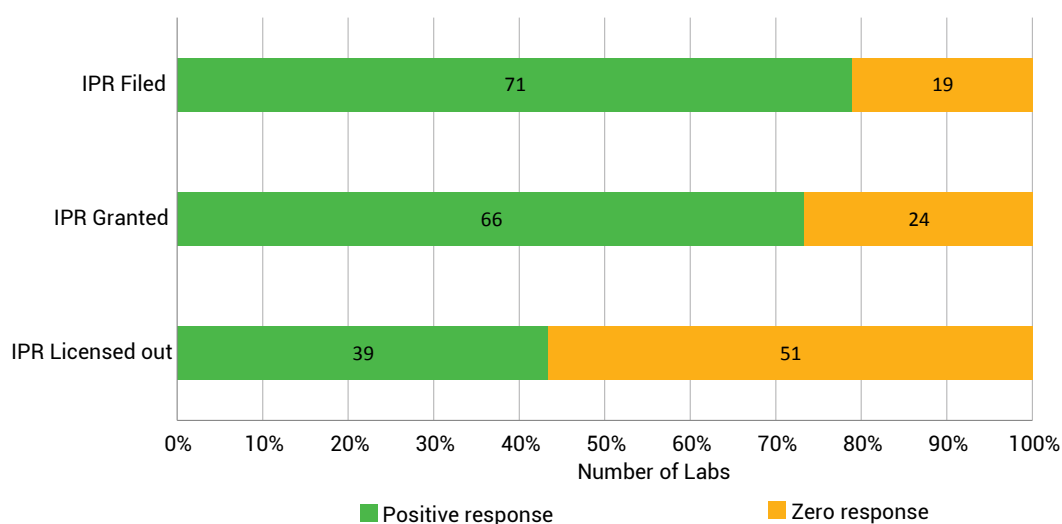
The chart captures the data on how many labs are filing, being granted and have licensed out any IP (patents, trademarks, copyrights, plant variety) etc. The pattern observed is similar. Patents form the largest category of the IPR as can be seen when the two charts are compared.

Figure 6.13 - New services and/or products introduced per Rs.10 crores spent
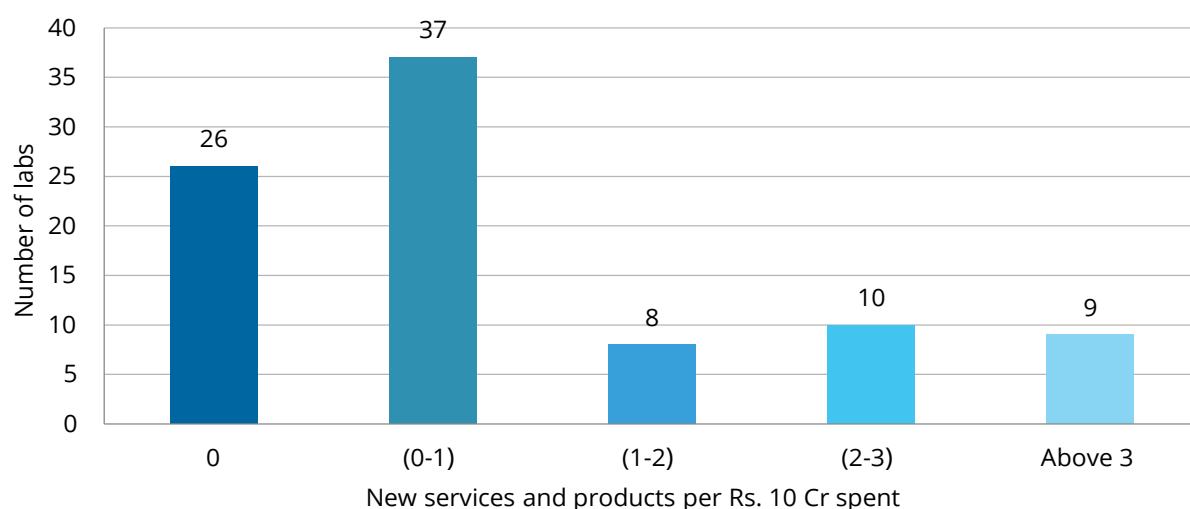
There were 26 labs, or nearly 30 percent of the labs, that did not introduce a single new product or service in the period under consideration. There were 45 labs that introduced up to 2 new products and/or services per Rs.10 Crores of budgetary support while 19 labs introduced more than 2 new products and/or services per Rs.10 Crores of budgetary support. The 19 labs that introduced more than 2 new products and/or services per Rs 10 Cr of budgetary support were dominated by labs from ICAR.

Sub-pillar 5: Commercialisation of technologies and revenue generation

Figure 6.14 - Extramural funding from government and non-government sources (%)
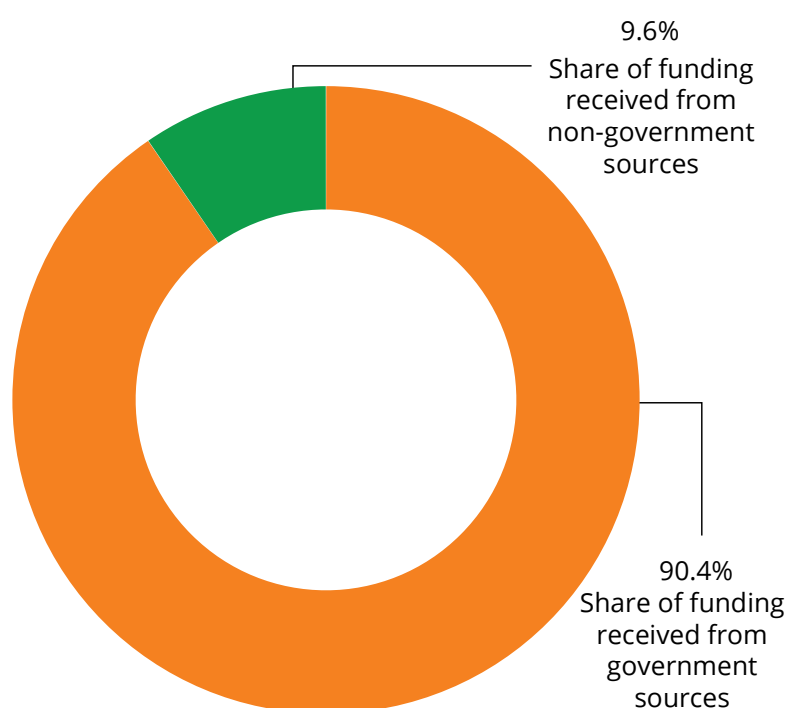
The pie-chart here clearly illustrates that the bulk of extramural funding received by the labs is from government sources. Looking at the extramural funding received from government sources, there are 63 labs that received less than Rs 2 Cr of extramural funding for every Rs 10 Cr of budget spent. There were around 18 labs that received more than Rs 4 Cr through extramural funding for every Rs 10 Cr of budget spent. Of these 18 labs, there were 7 DBT labs, 5 ICAR labs, 2 DST labs, 1 ICMR lab and the balance from other central government ministries.

Figure 6.15 - Extramural funding received from government per 10 crore of rupee spent
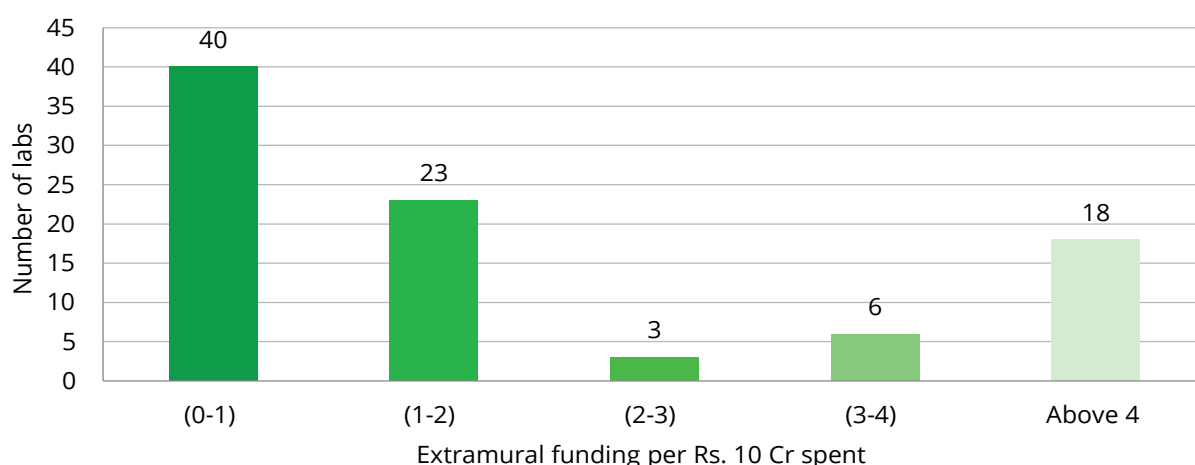
Around 40 percent of the labs did not receive any extramural funding from non-government sources. There were 2 labs that received more than Rs.4 Crores through extramural funding for every Rs 10 Crore of budget spent. These two labs were from ICMR and DBT. Most of the labs that did receive any extramural funding from non-government sources received up to Rs.1 Crore for every Rs.10 Crores of budgetary support.

Sub-pillar 6: Collaborative research

Figure 6.16 - International and National industry project collaborations
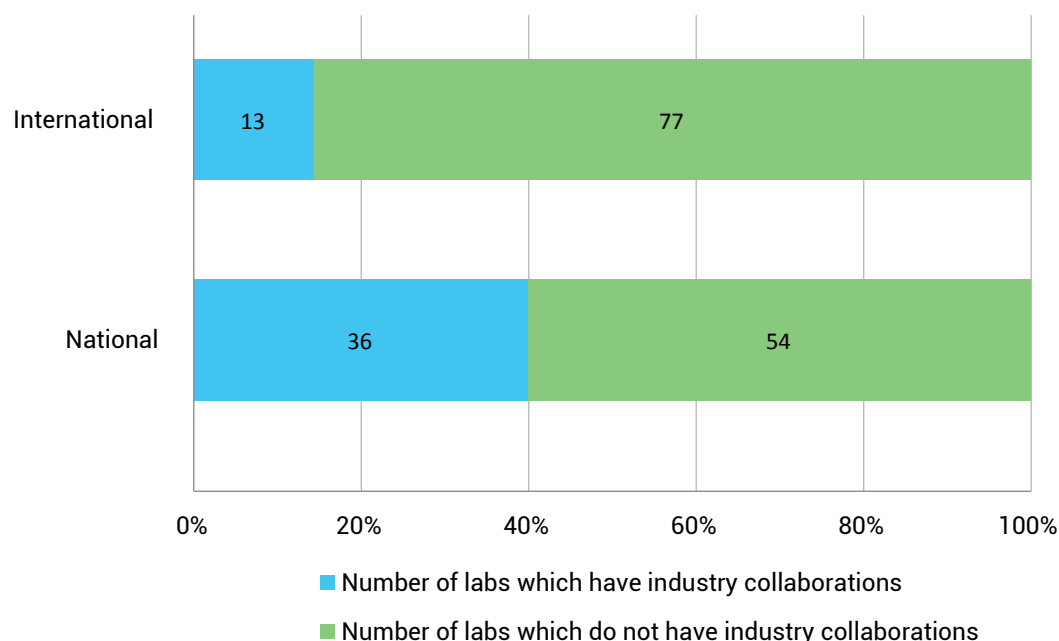
When it came to project collaborations, there were just 13 labs that had ongoing international industry collaborations while 36 labs had ongoing national industry collaborations. There were 54 labs that had absolutely no national or international collaboration with industry.

There were a lot more labs that had project collaborations ongoing with both international and national academic and/or other research institutions. There were 65 labs engaged in international collaborations and 80 labs engaged in national collaborations when it came to projects. There were 10 labs that had no international or national project related collaborations. As can be seen in the chart above, for a majority of the labs the share of international or national collaborations in their projects was up to 20 percent.

Figure 6.17 - Share of academic collaborations in projects executed by the labs (%)
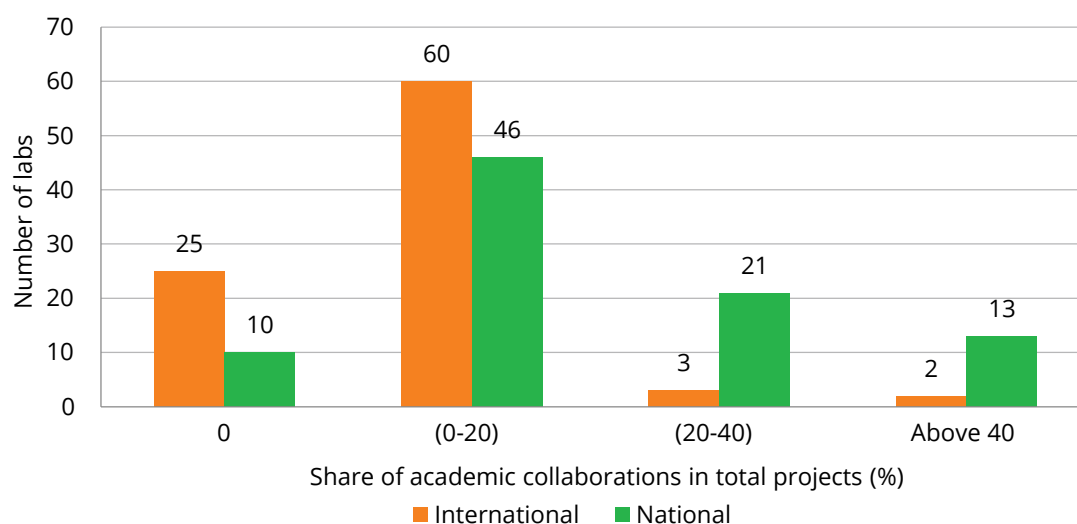
Figure 6.18 - Publication collaborations: International and National (%)
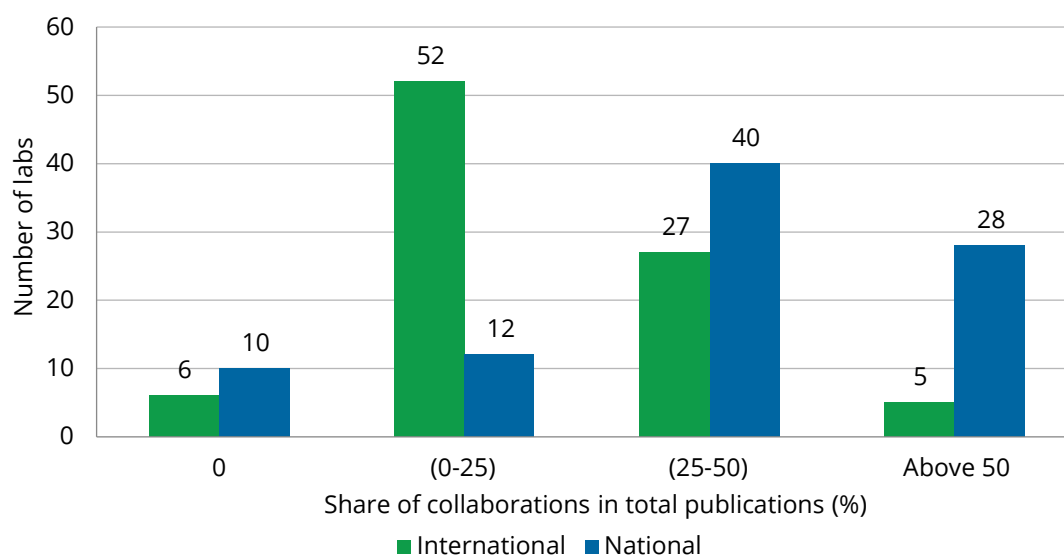
There were 86 labs out of 90 that had either international or national collaborations when it came to publications. For 52 labs, the share of international collaborations in their total publications was up to 25 percent.

With respect to the share of national collaborations in their total publications, 40 labs had a share between 25 percent to 50 percent. Nearly a third of the labs also had a share of over 50 percent for national collaborations in their total publications.

Key takeaways: 02

○ There were 16 labs that had more than 10 percent of their publications in the top 10 percent journals. For this set of 16 labs, there was a higher share of international and national collaborations in their total publications compared to labs that had fewer publications in the top 10 percent journals. Increased collaborations has the potential to contribute to greater sharing of resources as well as a wider reach of the work of individual labs.

○ It was observed that despite some labs having fewer publications per 100 scientific staff, did have a relatively larger impact measured by either citations received per 100 scientific staff or the share of their publications that made it to top 10 percent journals.

○ The impact of labs working in healthcare research is visible from the data on publications relative to some of the other fields. Several labs working in critical areas of sustainable agriculture and climate sciences have the potential to increase their reach and impact through wider dissemination and publication in peer reviewed journals, their domain knowledge and experience obtained in a developing country context.

○ Many labs are not currently engaged in licensing out their patents. This is one area where labs could be provided assistance by their respective departments/ministries or industry associations in facilitating a wider access to the technologies being developed by the labs.

○ Close to thirty percent of the labs did not introduce a single new product or service in the three years under consideration. There were 19 labs that introduced more than 2 new products and/or services per Rs 10 Cr of budgetary support and were dominated by labs from ICAR.

○ There is significant scope for increased project collaborations not just with industry but also with other academic and/or research institutions. This will also possibly contribute to diversifying the sources of extramural funding away from mainly government sources, and through international projects also allow for greater international funding.

Pillar 3: Organisational Effectiveness

As seen in the chart above on the pillar wise scores, the average score for this pillar was relatively higher than the average scores for the other two pillars. The indicators considered here look at the number of new research fields/innovations/services that have been introduced by a lab in each year under consideration, the share of scientists and project based (contractual) researchers in the overall staff, indicators on governance that include for example whether the labs have ethics guidelines and policies in place, a sexual harassment mitigation cell, indicators on EDI and lastly the amount spent towards internal capacity building of the staff.

- There were 89 labs that introduced at least one new research field/innovation/ service on average every year for the period under consideration, of which 43 labs introduced 3 new research fields/innovations/services each year.

- Around 50 labs had a share of permanent scientists and project based (contractual) researchers in total staff that was greater than 50 percent. The median share of the budget spent in R&D was around 35 percent for the Basic R&D labs.

- In terms of governance, the labs were following best practices for nearly all the parameters, except when it came to deployment of a software to track and manage research projects through their lifecycle where just 57 percent of the labs had done so.

- A majority of labs were also found wanting when it came to having an EDI cell, while the share of women in research staff was between 25 percent to 50 percent for around 53 labs. There were 62 labs for whom more than 50 percent of their staff consisted of young researchers (below the age of 40).

- Out of the 90 labs, 70 labs spend less than 1 percent of their budget on training and skill upgradation of their staff.

Sub-pillar 7: Mandate alignment

All labs have a scientific strategy in place to work towards their mandate. Nearly all the labs as part of their mandate have defined existing problems related to the social and economic situation of the nation and have been working towards solving these problems. Many of the labs have also seen the mission and vision for their research evolve over the past five years.

Figure 6.19 - New research fields/innovations/services introduced by the labs (upto 3)
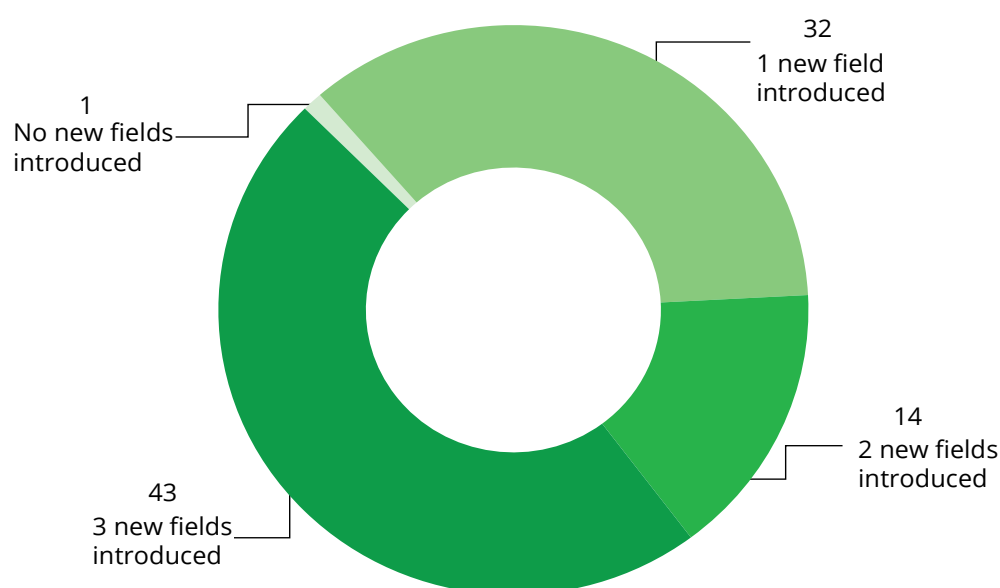
As can be seen in the chart, there were 43 labs that introduced 3 new research fields/ innovations/ services in each year for the period under consideration, while 14 labs introduced at least 2 new fields/ innovations/services in each year. While the labs have provided the necessary details of the fields or innovations or services introduced, it would require domain experts to evaluate the impact of these new fields/ innovations/ services introduced.

Sub-pillar 8: Resource management

Figure 6.20 - Share of permanent scientists and contractual researchers to overall staff
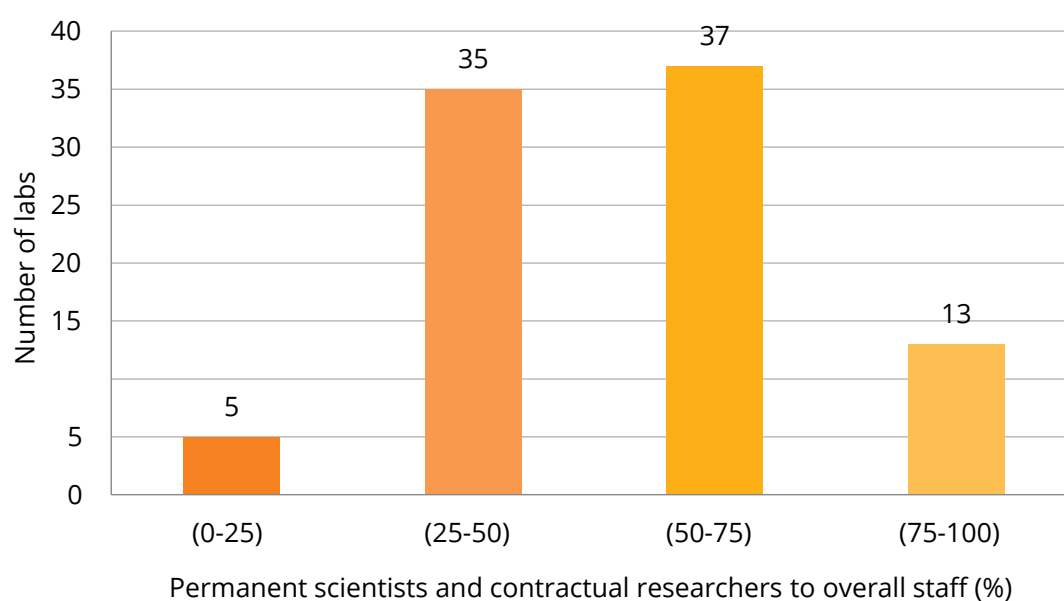
For 50 labs, the share of permanent scientists and project based (contractual) researchers in total staff is over 50 percent. There were 5 labs for whom the share of permanent scientists and project based (contractual) researchers was less than 25 percent.

The median value for R&D and S&T expenditure as a share of a lab's overall budget was close to 35 percent for the 90 basic labs. The R&D and S&T related expenditure was meant to include all research related expenditure including salaries paid to the researchers and travel costs related to research etc. and was required to exclude administrative and other running costs. There is a possibility of under-reporting by labs when it comes to R&D and S&T expenditure from a computational standpoint. While nearly a third of labs that did report their R&D and S&T related expenditure as a share of the overall budget to be in excess of 75 percent, the median value being so low does raise some concern about the quality of information reported by the labs. It is quite likely that the labs may be allocating a higher share of their budget to R&D and S&T activities.

Sub-pillar 9: Governance

A. Effectiveness of Management System

Table 6.1 - Effectiveness of Management System

Question	Share of labs that responded 'Yes' (%)
Does your organisation effectively communicate its objective and strategy to its staff?	100
Does your organisation have all requisite SOP/guidelines for its processes?	99
Are there initiatives in place to promote intra-organisational collaborations?	99
Has your organisation deployed any software system to track and manage research projects through its lifecycle, from conception to completion?	57
Does your organisation have necessary ethics guidelines and policies in place?	99
Does your organisation have a sexual harassment mitigation cell with requisite policies and procedures?	100
Does your organisation have a public grievance redressal cell?	97

As can be seen in the table above, nearly all labs have adhered to best practices in terms of communicating its strategy to its staff, establishing necessary guidelines for its processes, promoting collaborations within the organisation, having the necessary ethics guidelines in place, have established a sexual harassment mitigation cell with necessary policies and also have public grievance redressal cell. The one parameter where nearly 40 percent of the labs are found wanting is with respect to deploying a proper MIS to track and manage the lab's research programmes and projects.

Sub-pillar 10: Equity, diversity, and inclusion

Figure 6.21 - Provision of EDI cell and differently-abled friendly facilities

Number of labs that responded 'Yes'   **Number of labs that responded 'No'**
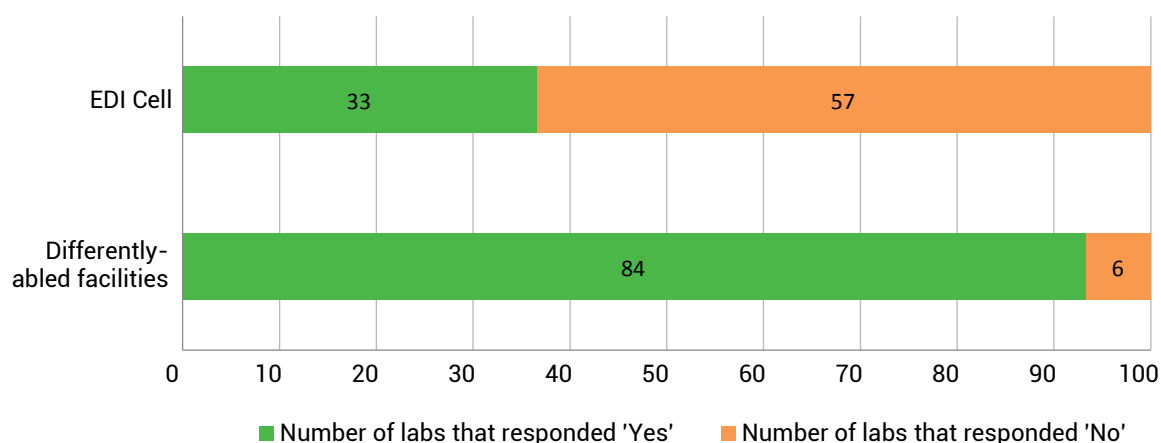
Despite the growing awareness and importance of equity, diversity and inclusion, there were only 33 labs said they had EDI cells. It would be important for all labs to continue to strive towards adopting objectives of promoting equity, diversity and inclusion at the workplace, and also establishing the necessary mechanism in the form of a cell or committee that could address any issues that may arise.

Figure 6.22 - Share of young scientists and women scientists to the total scientific and research staff
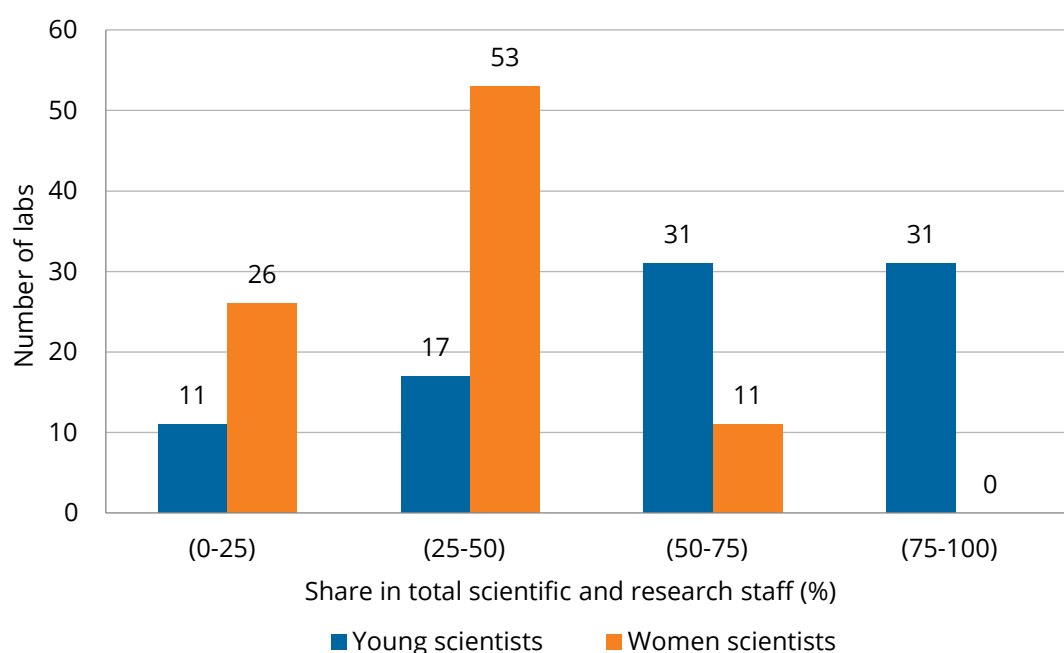
With respect to women scientists as a share of the total scientific and research staff, there were 53 labs whose share of women scientists was between 25 and 50 percent while 11 labs had a share between 50 to 75 percent. There is scope for 26 labs to increase the share of women scientists in their scientific and research staff. These 26 labs include 8 ICAR labs, 5 CSIR labs, 3 DST labs, 2 ICMR labs and the remaining labs from other central government ministries. In addition, there were 62 labs for whom more than 50 percent of their scientific and research staff were young researchers (below the age of 40).

Sub-pillar 11: Internal capacity building

Figure 6.23 - Share of the total budget spent on training and skill up-gradation of the staff (%)
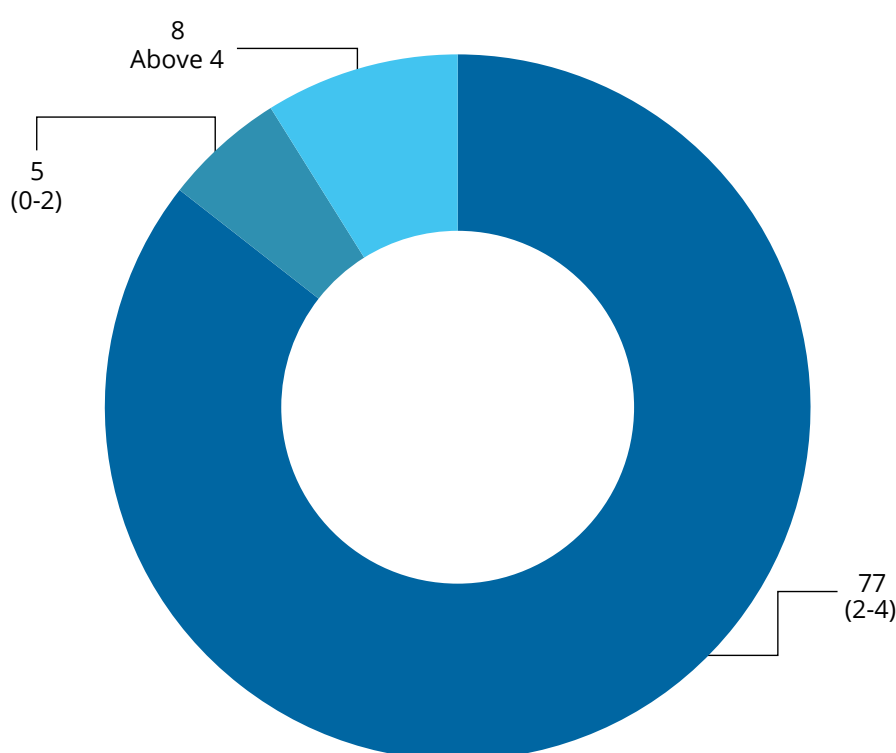
The expenditure being captured here includes training for the administrative staff as well as the scientific and research staff. Most labs have allocated very little of their budget towards training their staff. Of the 90 basic labs, there are 77 labs that spend between 0 and 2 percent of their budget towards training or on opportunities for skill upgradation of their staff. In fact, of these 77 labs, there are close to 70 labs that spend less than 1 percent of their budget on training.

Increased expenditure on training and skill upgradation would be important to complement the R&D and other activities of the labs. We have already seen the median spend on R&D and S&T as a share of the overall budget being quite low at 35 percent. Thus a majority of labs may need to take a holistic approach towards their R&D and S&T expenditure that also sees increased allocation towards training of their staff. Training of the administrative staff to support the scientific and research staff would also be very important.

Key takeaways: 03

- While nearly all the labs were seen to introduce at least one new research field/ innovation/service per year, it would be important for domain experts to review these new introductions to evaluate their impact.

- The low level of median R&D and S&T spending as a share of a lab's budget would need to be revisited to better understand if this is more than a reporting error by a significant number of labs.

- It would be important for all labs to consider deploying a software based MIS to track and monitor the progress of their projects. This would be a much needed and effective management tool to ensure greater impact of the projects being undertaken and also assist in the planning for any remedial measures that may need to be undertaken.

- The growing importance of EDI at the workplace means that all labs should establish a mechanism by way of a cell or committee that ensures this important practice is adhered to.

- Other important staff related measures that would also complement the research activities of the lab would mean that all labs would need to consider increasing their spending on training and skill upgradation of their staff.

Chapter 7
APPLIED R&D LABS

Applied research by definition is an original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective. The TRL levels of the technologies developed by these laboratories were 5 or higher. There were 128 labs that categorised themselves as Applied R&D labs. This chapter analyses the responses of laboratories that chose to categorise themselves as doing Applied R&D.

There were 128 labs that categorised themselves as Applied R&D labs, of which there were 72 labs that were undertaking pure applied R&D while the remaining 56 labs were hybrid in nature i.e. they were also undertaking basic and/or applied R&D.

Laboratories from CSIR and ICAR accounted for nearly 70 percent of the 128 applied R&D labs. When one considers the sample of R&D labs that were only engaged in applied R&D, the largest numbers of labs came from ICAR, followed by CSIR, ICMR, DBT and the Ministry of Ayush. The average budget for the overall sample of 128 applied research labs was around Rs 64 crores, while it was around Rs 62 crores for the 72 labs that were engaged in only applied R&D. With respect to scientific staff, the average number of scientific staff per laboratory for the overall sample of 128 labs was around 150, with this number dropping to around 145 scientific staff per laboratory for the labs engaged in only applied R&D.

Figure 7.1 - Sub-pillar wise average scores for Applied R&D Labs

S.No.	Sub-pillar Name	Pillar Name
1	Contribution to SDGs and national programmes	Socio-economic impact
2	Employment generation and human resource development	
3	Scholarly research, development output and quality	Science, technology and innovation excellence
4	Development and innovation output and quality	
5	commercialisation of technologies and revenue generation	
6	Collaborative research	
7	Mandate alignment	Organisational effectiveness
8	Resource management	
9	Governance	
10	Equity, diversity, and inclusion	
11	Internal capacity building	

Figure 7.1 captures the average scores of the labs on the various sub-pillars. The applied labs on average have performed relatively better on sub-pillars 7 to 11 compared to the other sub-pillars.

The pillar-wise average scores have been captured in Figure 7.2. Labs have generally performed significantly better on the Organisational effectiveness pillar compared to the other two pillars.

Figure 7.2 - Pillar-wise scores for Applied R&D Labs
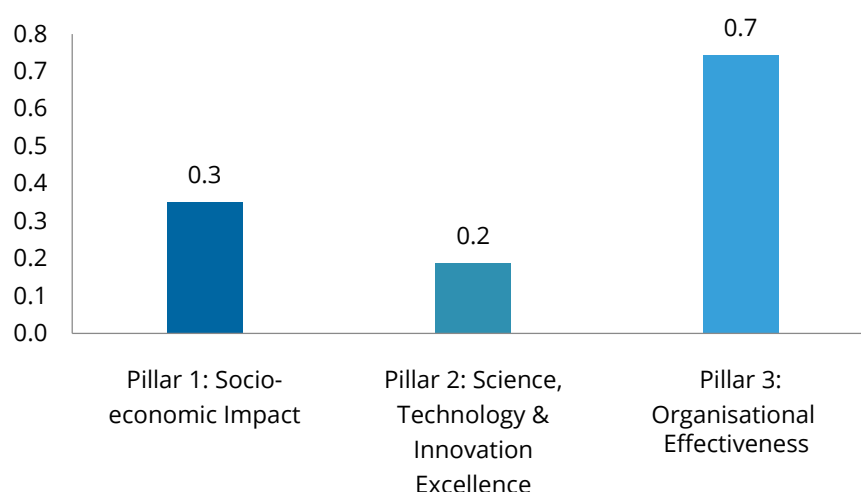
Some of the areas that the labs may wish to focus on going forward include increased collaborations on projects with industry and also increasing their international collaborations. For these collaborations to happen all labs should aim to obtain necessary accreditations for their lab procedures. This would not only contribute to the labs gaining recognition both nationally as well as internationally, but would further contribute to their earnings through consultancies and also have greater extramural funding from non-government sources. Not all labs are engaged in licensing out their patents. Given the nature of the research, labs that are patenting their technologies could also consider licensing out these commercially. Furthermore, labs should look to engage more with the startup ecosystem by providing either incubation support or providing access to their facilities and research capabilities. Many more labs should also consider supporting outside researchers from local colleges by providing them access to their facilities.

The following section considers the performance of the labs focusing on around 50 key indicators that drive the performance in each of the sub-pillars mentioned in Figure 7.1, and thereby the overall pillar. The weights attached to these 50 indicators account for around 80 percent of the total framework. For comparability, where necessary the data has been scaled by either 100 scientific staff or Rs 10Cr of budget spent.

Pillar 1: Socio-economic Impact

The key indicators in the pillar on socio-economic impact that have been captured below include the number of technologies (with TRL levels between 0 and 4) targeted towards SDGs or national programmes, the number of projects being undertaken by the labs, the targeted beneficiaries of the labs programmes, startups incubated, and the, number of degrees (PhDs, masters, undergraduate) awarded by the labs. The data presented in the charts below are based on an average of the three years under consideration, namely FY2018, FY2019 and FY2020.

- There were 17 labs that had not developed any technologies. Around 61 labs had developed upto 10 technologies (targeting SDGs and/or national programmes) and 38 labs that had developed more than 15 technologies per hundred scientific staff.

- Around 48 percent of the labs are engaged in more than 60 projects per hundred scientific staff. On the higher end, there were 37 labs or around 30 percent of the labs that executed more than 80 projects per hundred scientific staff.

- The primary beneficiaries of the output from the basic labs are government departments followed by individuals.

- Around 22 percent of the labs were incubating startups.

- Around 40 percent of the labs award less than 10 educational degrees (combined PhDs, Masters and undergraduate degrees). There were 91 labs that offered PhD degrees of which 25 percent said the PhD dissertations of their students had been reviewed by a foreign assessor.

Sub-pillar 1: Contribution to SDGs and national programmes

Figure 7.3 - Technologies targeted towards SDGs & National Programmes (TRL 5 or higher)
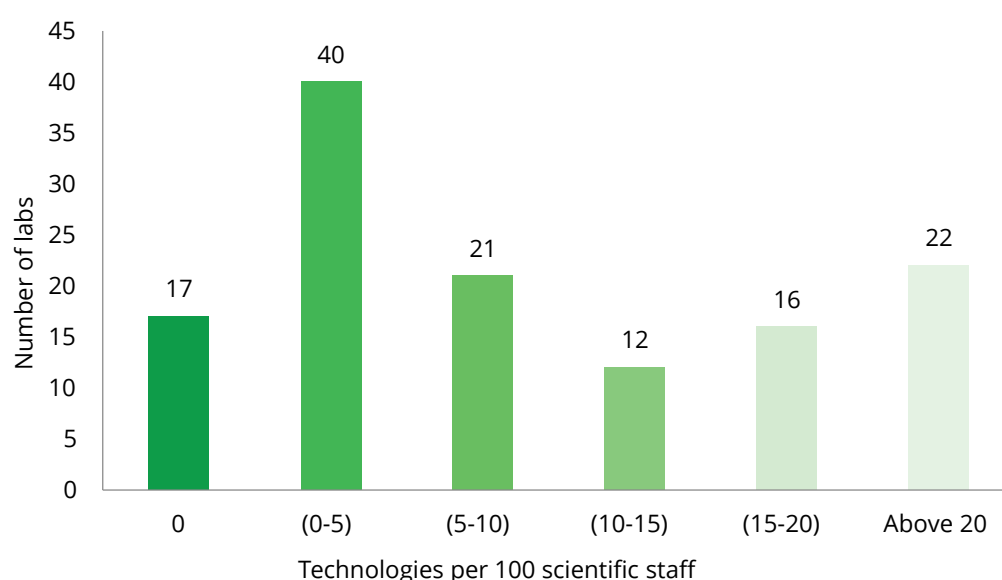
Of the 128 labs, there were 17 labs that had not developed any technologies with TRL 5 and higher (targeting SDGs and/ or national programmes). There were 61 labs that had developed up to 10 technologies per 100 scientific staff while 22 labs had developed more than 20 technologies per 100 scientific staff with TRL 5 and higher.

The 22 labs with 20 or more technologies per hundred scientific staff included 15 labs from ICAR, 2 labs from MoEFCC, and 1 lab each from CSIR and ICMR. The remaining 3 labs were from other central government ministries.

Figure 7.4 - Projects executed per 100 scientific staff
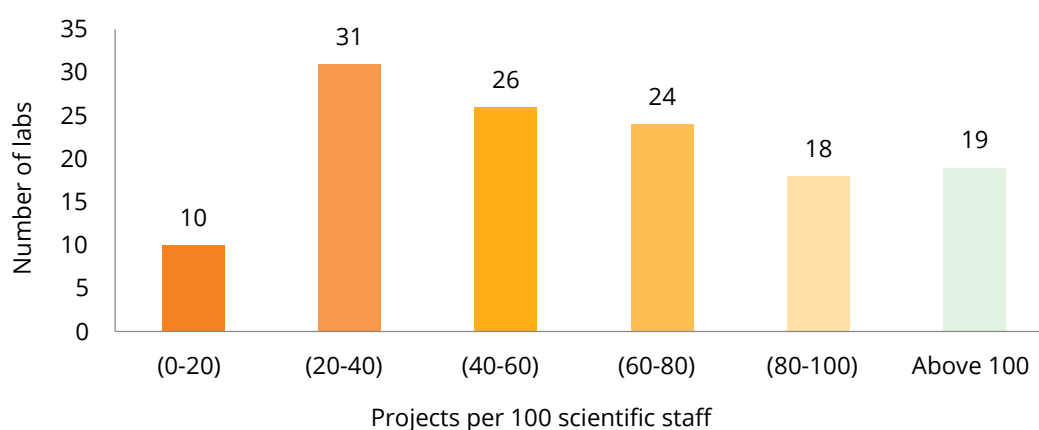
There were 67 labs that were undertaking upto 60 projects per 100 scientific staff, while the remaining 61 labs were engaged in more than 60 projects per 100 scientific staff. Of these 61 labs, there 19 labs that were engaged in more than 100 projects per 100 scientific staff.

Of the 19 labs that were engaged in more than 100 projects per 100 scientific staff, there were 7 labs from ICAR, 3 labs from DBT, 2 labs from ICMR, 2 labs from CSIR, 1 lab from MoES and 4 labs from other central government ministries.

Figure 7.5 - Beneficiaries of organisation's programmes
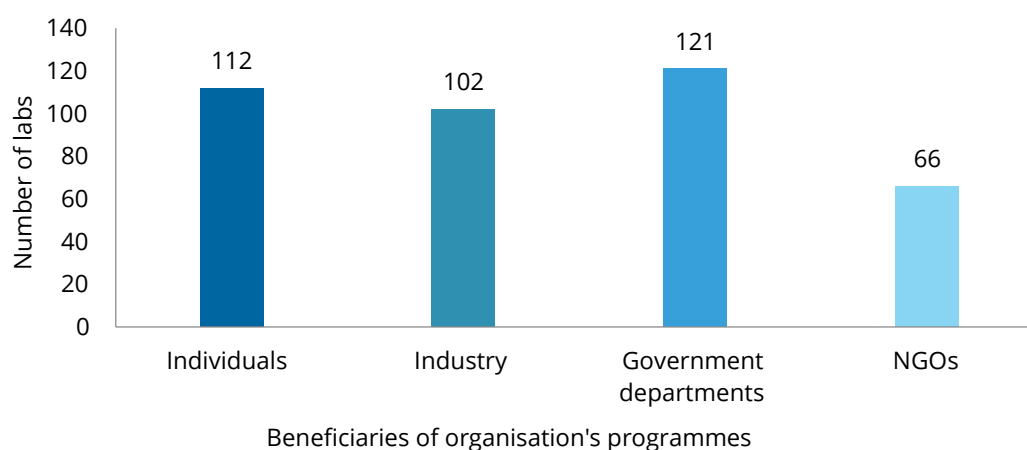
Nearly all the applied labs were targeting government departments through their research and programmes. Individuals were targeted by close to 88 percent of the labs while around 80 percent of the labs were also targeting industry through their programmes. Over 50 percent of the labs were targeting NGOs through their work.

Sub-pillar 2: Employment generation and human resource development

Figure 7.6 - Incubation of startups

29
Number of labs
that incubated
startups

99
Number of labs
that did not incubate
startups
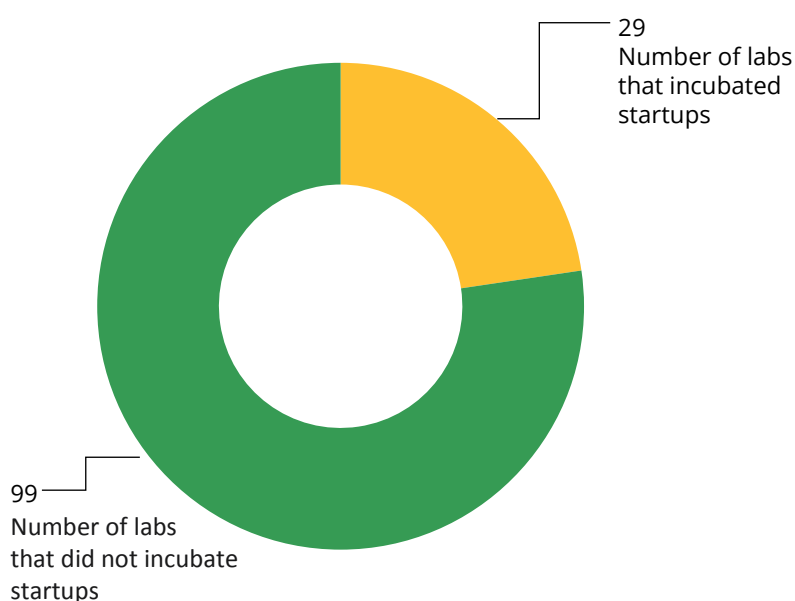
There were 29 labs undertaking applied R&D that were incubating startups while 99 labs did not provide any incubation support to startups.

Figure 7.7 - PhDs, Masters and Graduate degrees awarded per 100 scientific staff
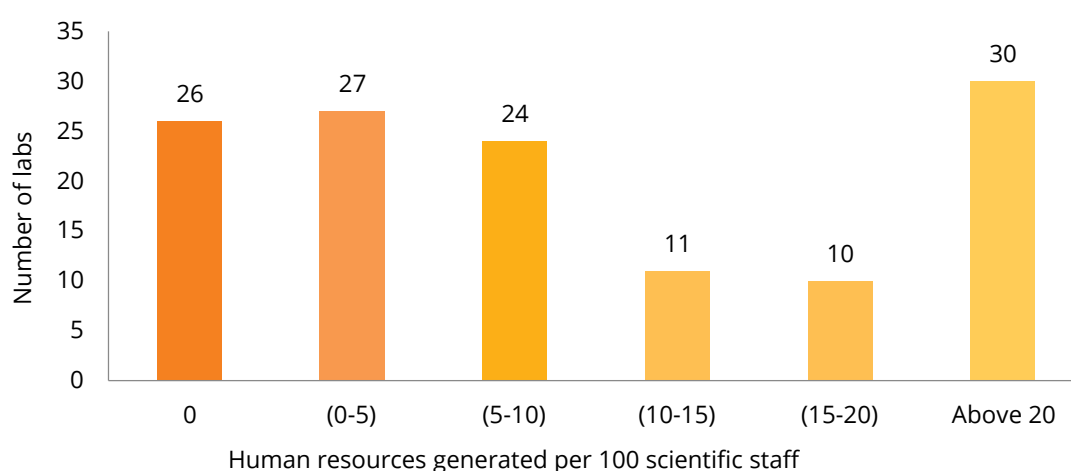
There were 26 labs performing applied R&D that did not offer or award any degree in the period under consideration. Around 51 labs offered up to 10 degrees per 100 scientific staff while the remaining 51 labs offered more than 10 degrees per 100 scientific staff. The degrees awarded are a combination of PhDs, Masters and undergraduate degrees. There were 30 labs that in fact awarded more than 20 degrees per 100 scientific staff. Of these 30 labs, there were 15 labs from ICAR, 6 labs from CSIR, 4 labs from ICMR and the remaining 5 labs were from other central government ministries. Of the 26 labs that did not award any degree, a majority of the labs were from ICAR.

There were 112 labs out of the 128 that did not offer any graduate degrees while 68 labs did not offer any master's degree. There were just 37 labs that did not offer any PhD degrees. Of the 91 labs that awarded PhD degrees, around 25 percent of the labs mentioned that the PhD dissertations had been reviewed by one or more foreign assessors.

Key takeaways: 01

- There were 17 labs that had not developed any technologies. Of these, 16 were from major scientific agencies.

- While 38 labs that had developed more than 15 technologies per hundred scientific staff and 37 labs that executed more than 80 projects per hundred scientific staff, there were 18 labs among these which developed a higher number of technologies as well as executed a higher number of projects.

- The primary beneficiaries of the output from the basic labs are government departments. Labs may wish to start engaging with NGOs for increased socio-economic impact of their work.

- More labs could consider incubating startups or providing support through their resources to startups, both in terms of research support as well as access to their infrastructure. Many of the labs are engaged in developing technologies having TRL levels between 5 and higher and should be incentivised to engage more with the start-up ecosystem to become a provider of a wider source of technology for industry.

- There were more labs offering PhD degrees compared to Masters or undergraduate degrees. Closer tie ups with the higher educational institutions would allow for easier access to the infrastructure and resources of the labs for students pursuing science and engineering degrees.

Pillar 2: Science, technology and innovation excellence

The indicators considered below pertain to publication output, commissioned technical reports, citations received for the publications, the share of publications in top 10 percent journals, IPR filed, granted and licensed out, domestic and international technology transfer, new services and/or products introduced, earnings from government and non-government

sources, external funding received by the labs and collaborations on projects as well as publications.

○ There were 43 labs or around 33 percent of the labs that had greater than 60 publications in peer reviewed journals per 100 scientific staff per year while just 20 percent of the labs had more than 600 hundred citations per 100 scientific staff.

○ There were 58 labs that had not prepared any commissioned technical reports while only 30 labs had prepared more than 4 commissioned technical reports per 100 scientific staff.

○ A majority of the labs were seen to be engaging in filing patents and a majority had also obtained patents, however only around a third of them are seen to be licensing out their patents. 70 percent of the labs had transferred technologies developed by them domestically and very few labs had transferred any technologies internationally.

○ There were 24 labs that had not introduced a single new product or service in the three years under consideration, while 30 labs that introduced more than 2 new products and/or services per Rs 10 Cr of budget spent over the same period.

○ The main source of external funding for the labs is from other government funding, while sources of earnings are mainly through consultancies followed by training.

○ Several labs are not collaborating with industry on projects. Around 60 percent of the labs are engaged in international academic collaborations for up to 20 percent of their projects.

Sub-pillar 3: Scholarly research, development output and quality

Figure 7.8 - Number of publications per 100 scientific staff
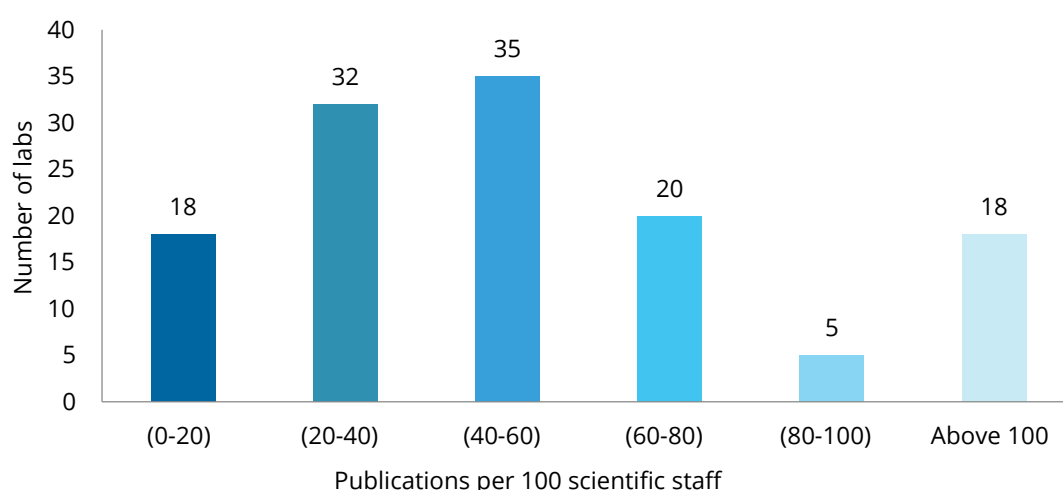
Around 66 percent of the labs or 85 labs had upto 60 publications per 100 scientific staff, while the remaining 34 percent or 43 labs had greater than 60 publications per 100 scientific staff. Of the 43 labs that had greater than 60 publications per 100 scientific staff, there were 16 ICAR labs, 14 CSIR labs, 5 ICMR labs, 4 DBT labs, 1 lab each from DST and MoES and 2 from other central government ministries.

Figure 7.9 - Commissioned technical reports per 100 scientific staff
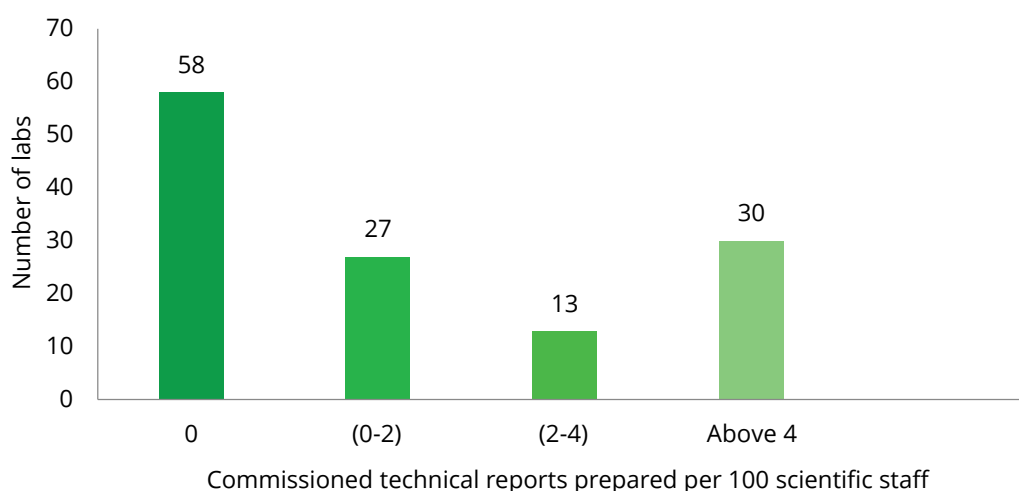
As can be seen in the accompanying chart, there were 58 labs that were performing applied R&D but did not produce any commissioned technical reports. There were around 40 labs that produced upto 4 commissioned technical reports per 100 scientific staff while there were 30 labs that produced more than 4 commission technical reports per 100 scientific staff.

Figure 7.10 - Number of citations per 100 scientific staff
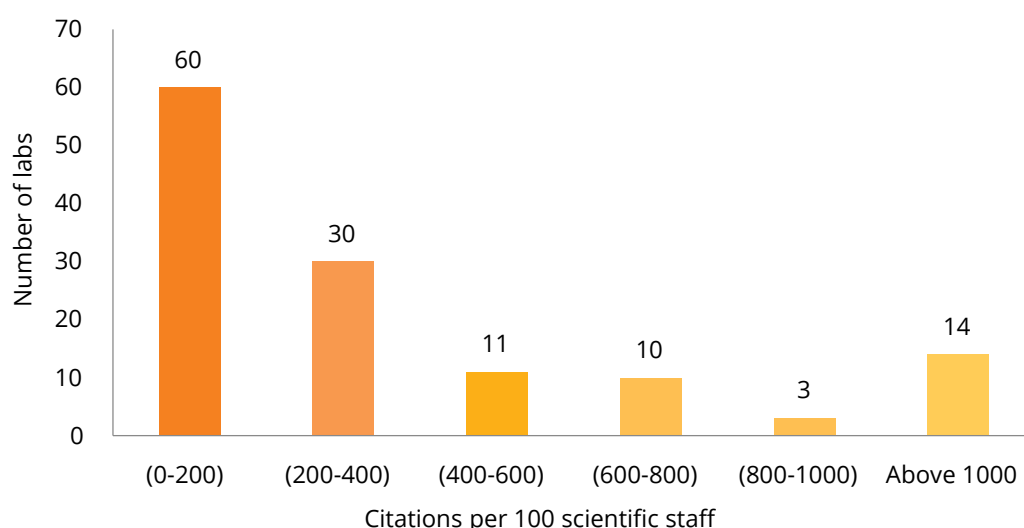
Within the category of applied R&D labs, there were around 27 labs on average that received over 600 citations per 100 scientific staff for their respective publications, while there were 101 labs that received upto 600 citations per 100 scientific staff for their publications. Of the

27 labs that received more than 600 citations per 100 scientific staff, there were 15 labs from CSIR, 6 labs from ICMR, 5 labs from DBT and 1 lab from ICAR. Furthermore, around 9 of the 27 labs were found to have less than 60 publications per 100 scientific staff suggesting a wider impact for these labs despite having a lower publication output.

Figure 7.11 - Share of publications in top 10% of journals
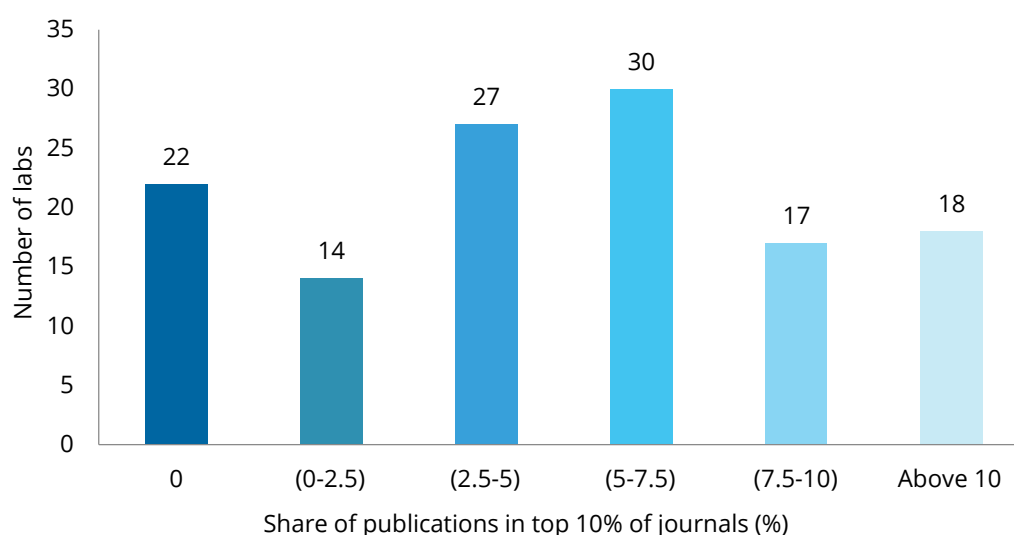
Around 22 labs did not have any publications in the top 10 percent of journals while there were 18 labs that had more than 10 percent of their publications in top 10 percent journals. Of these 18 labs, there were 6 CSIR labs, 4 ICMR labs, 3 DBT labs, 1 ICAR lab and 3 labs from other central government ministries. It is interesting to note that 11 out of the 18 labs had less than 60 publications per 100 scientific staff. Of the 22 labs that did not have any publications in the top 10 percent of journals, there were 19 labs that had less than 60 publications per 100 scientific staff.

Sub-pillar 4: Development and innovation output and quality

Figure 7.12 - Patents filed, granted and licensed out
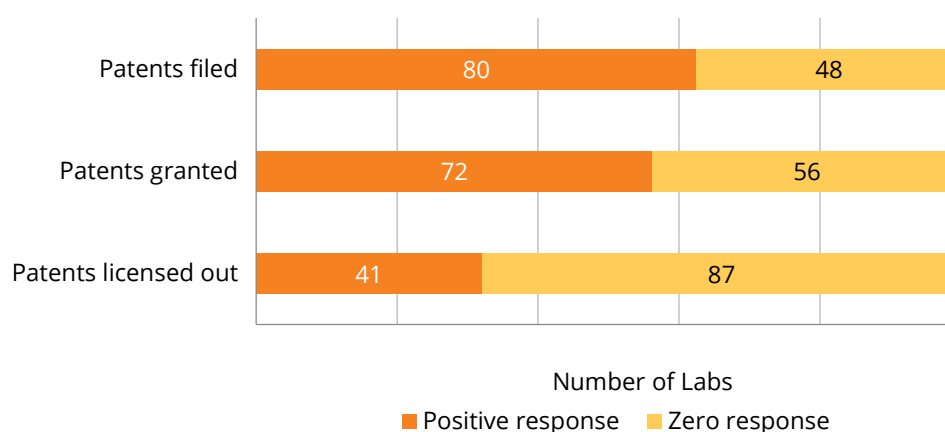
For Applied R&D labs, 63 percent of the labs had filed patent applications while 56 percent of the labs had obtained patents in the period under consideration. When it came to licensing out patents, just 32 percent of labs were licensing out their patents.

When one considers all IPRs (patents, trademarks, copyrights, plant variety etc.), there were 101 labs or 78 percent of the labs that filed IPRs while there were 97 labs or 76 percent that were granted an IPR in the period under consideration. However just 52 labs or 40 percent of the labs licensed out their IPR.

Figure 7.13 - Intellectual Property Rights filed, granted and licensed out

Number of Labs

■ Positive response   ■ Zero response
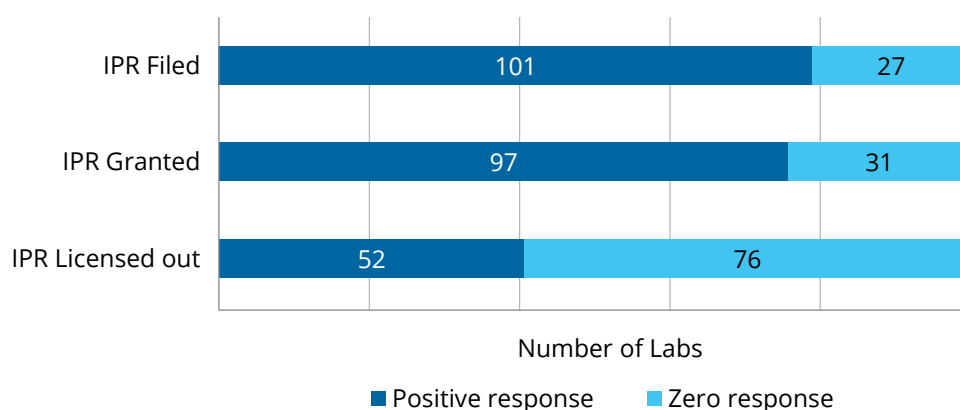
Figure 7.14 - Domestic and international technology transfer

Number of labs

■ Number of labs that transferred technologies
■ Number of labs that did not transfer technologies
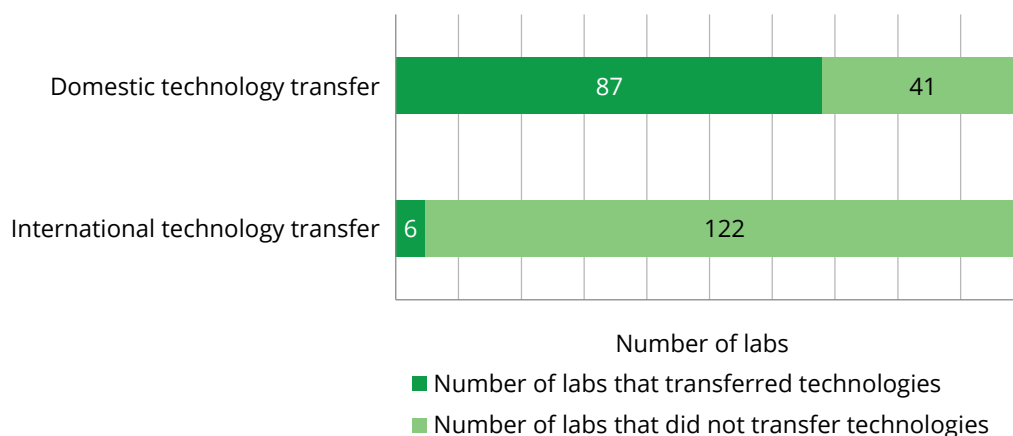
Of the 128 labs, 87 labs said they had transferred labs domestically. Very few labs had transferred any technologies overseas. The 6 labs that did transfer technologies overseas had also transferred technologies domestically and included 3 labs from ICAR, 2 labs from CSIR and 1 lab from DBT.

Figure 7.15 - New services and/or products introduced per Rs. 10 crores spent
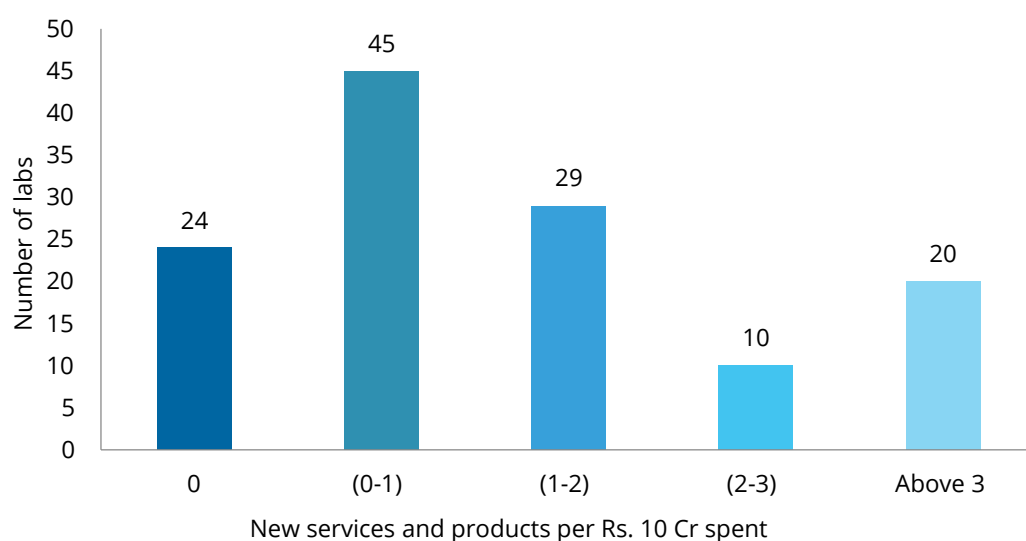
There were 24 labs that did not introduce a single new product or service in the period under consideration. There were 74 labs that introduced up to 2 new products and/or services per Rs.10 Crores of budgetary support while 30 labs introduced more than 2 new products and/or services per Rs.10 Crores of budgetary support. The 30 labs that introduced more than 2 new products and/or services per Rs 10 Cr of budgetary support were dominated by labs from ICAR.

Sub-pillar 5: commercialisation of technologies and revenue generation

Figure 7.16 - Patents filed, granted and licensed out
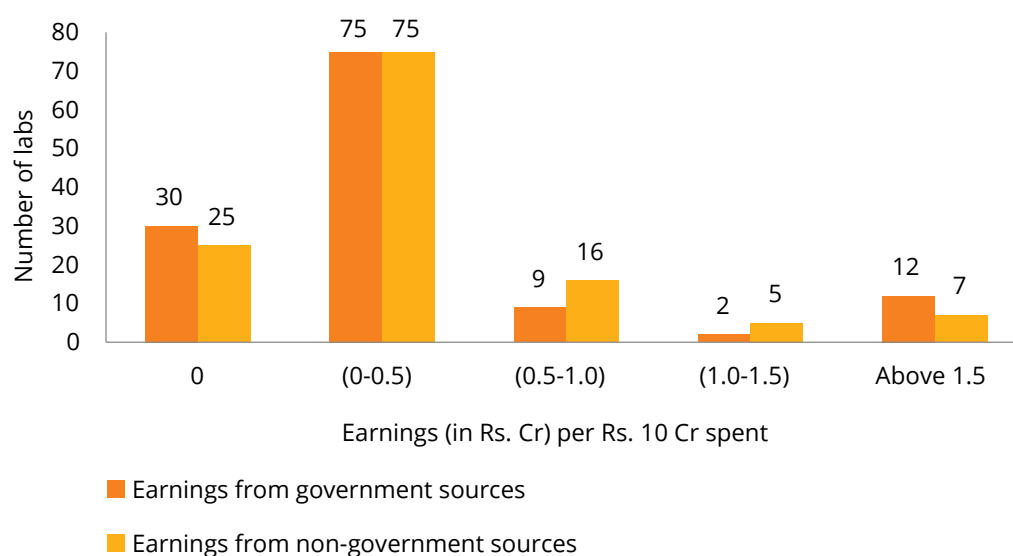
A majority of the earnings for the labs is coming by way of consultancies, followed by training and least by way of technology transfer as can be seen in the pie chart below. This holds true for earnings from government as well as non-government sources.

Of the 128 labs, there were 25 labs that did not have any earnings from non-government sources while 30 labs did not have any earnings from government sources. There were 6 labs that had no earnings from either government or non-government sources, with 4 of these labs coming from ICMR. There were 96 labs that said they had earned upto Rs 1.5 Cr per Rs 10 Cr of budget spent from non-government sources and 86 labs that had earned the same amount from government sources.

At the higher end of the earnings, there were 12 labs that had earnings of more than Rs 1.5 Cr per Rs 10 Cr of budget spent from government sources and 7 labs that had these earnings from non-government sources. Of these labs at the higher end, there were 4 labs that had earnings from both government and non-government sources that were greater than Rs 1.5 Cr per Rs 10 Cr of budget spent. While one of these labs was from MeitY, the remaining 3 labs were from other central government ministries.

Figure 7.17 - Sources of earnings
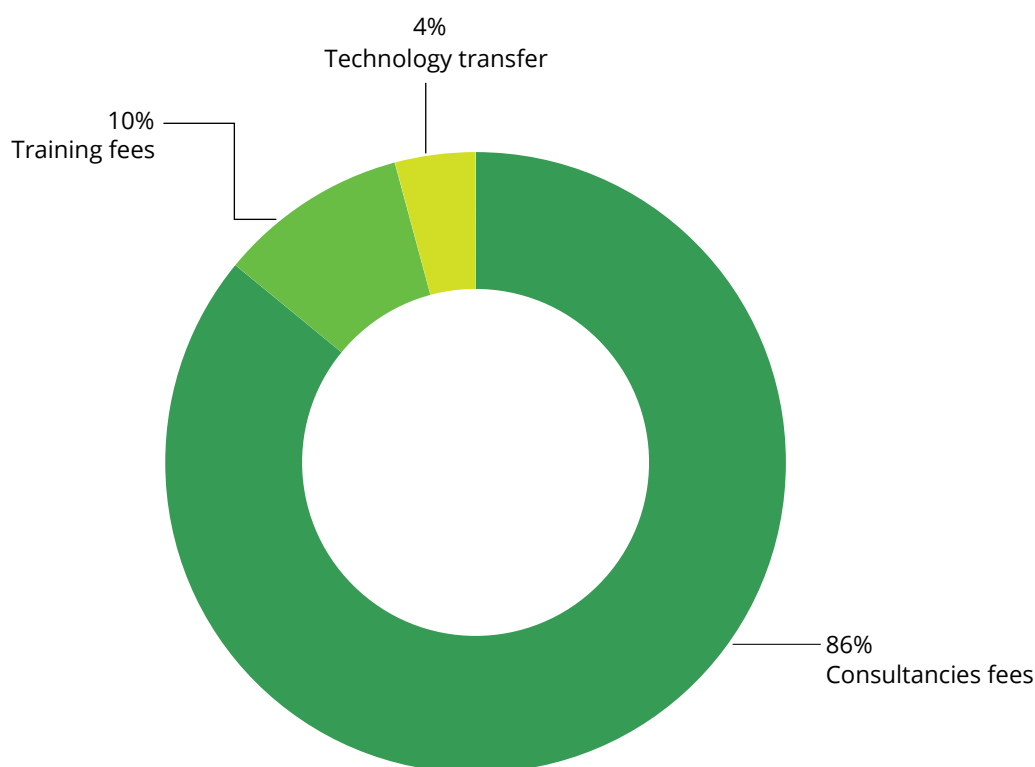
Figure 7.18 - Extramural funding received from government per 10 crore of rupee spent
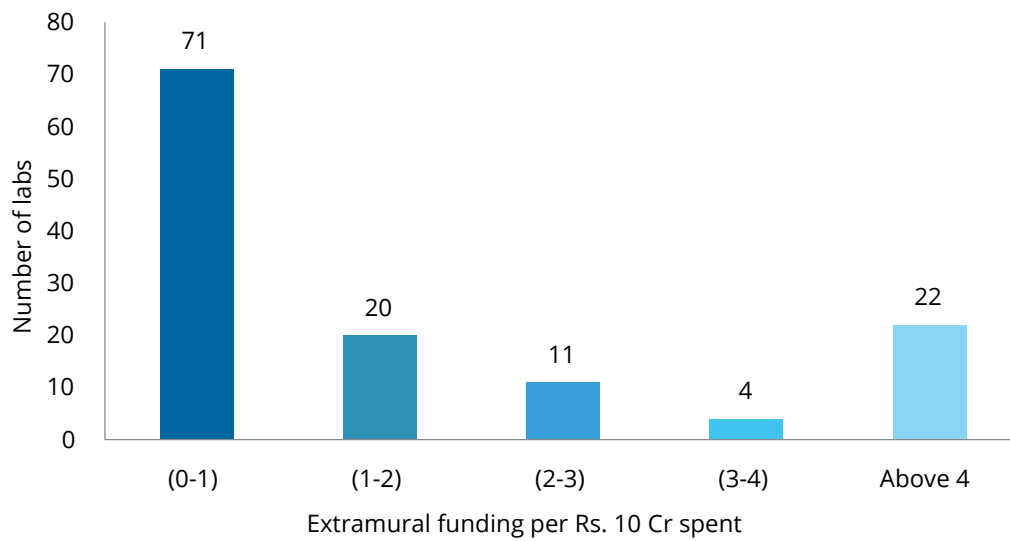
Figure 7.19 - Extramural funding from government and non-government sources

7%
Share of funding received from
government sources

93%
Share of funding received from non-
government sources
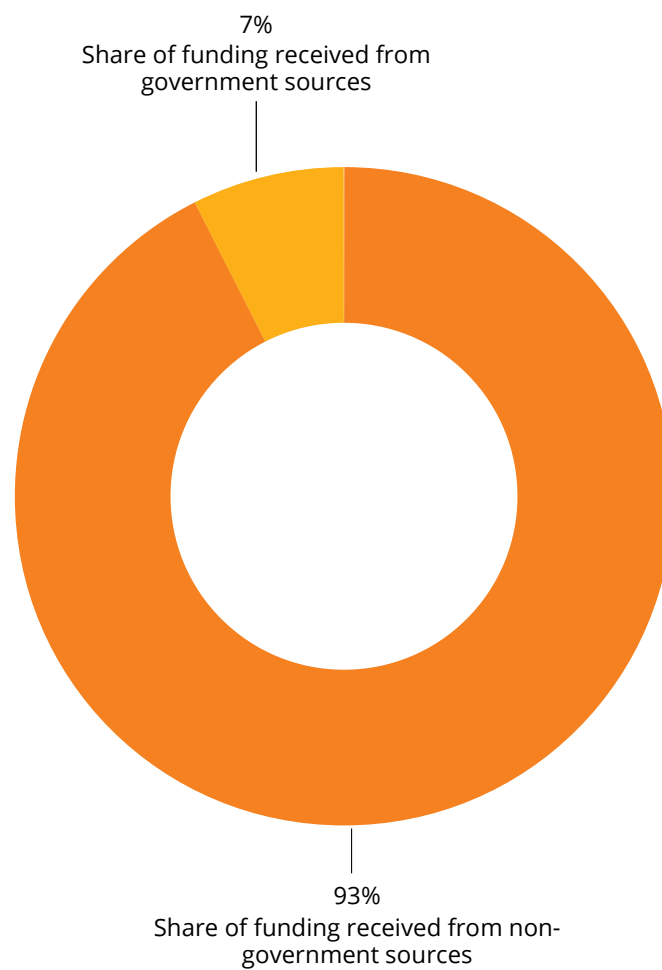
Over 90 percent of the extramural funding that the Applied R&D labs received during the period under consideration was from government sources. Looking at the extramural funding received from government sources, there were 91 labs that received less than Rs 2 Cr of extramural funding for every Rs 10 Cr of budget spent. There were around 22 labs that received more than Rs 4 Cr through extramural funding for every Rs 10 Cr of budget spent. Of these 22 labs, there were 7 ICAR labs, 5 ICMR labs, 2 CSIR labs, 2 DBT labs, 2 MeitY labs, 1 lab each from DST and MoEFCC and 2 labs from other central government ministries.

Around 40 percent of the labs did not receive any extramural funding from non-government sources. There were 2 labs that received more than Rs.4 Crores through extramural funding from non-government sources for every Rs 10 Crore of budget spent. These two labs were from ICMR and DBT. Most of the labs that did receive any extramural funding from non-government sources received up to Rs.1 Crore for every Rs.10 Crores of budgetary support.

Sub-pillar 6: Collaborative research

Figure 7.20 - International and National industry project collaborations
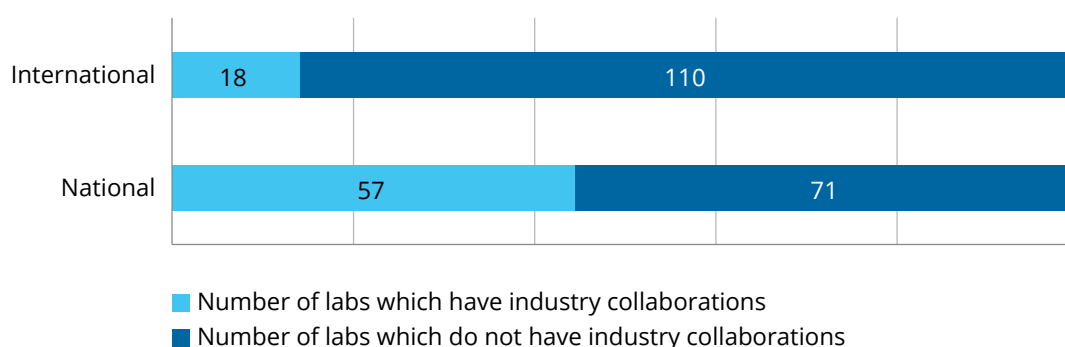
With respect to project collaborations, there were just 18 labs that had ongoing international industry collaborations while 57 labs had ongoing national industry collaborations. There were 70 labs that had absolutely no national or international collaboration with industry.

Figure 7.21 - Share of academic collaborations in projects executed (%)
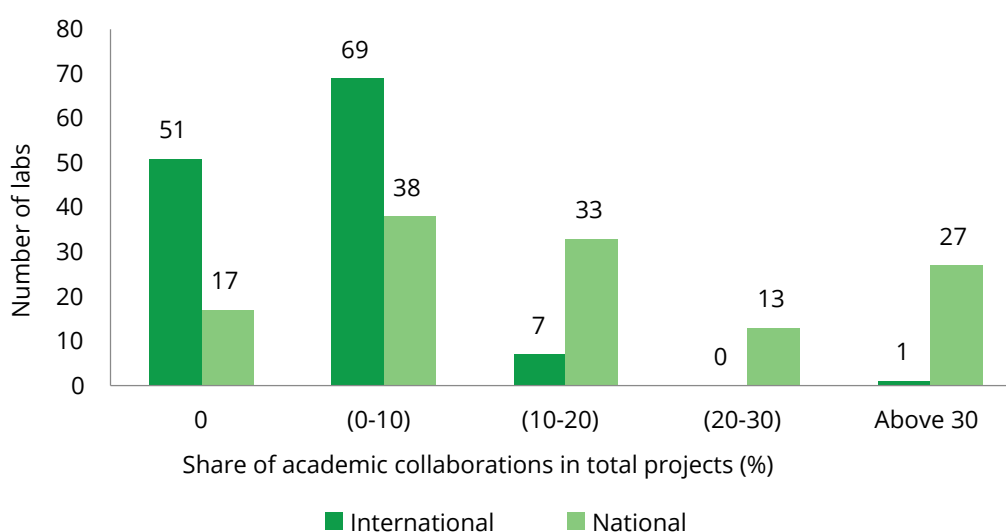
Compared to industry collaborations, there were a lot more labs engaged in project collaborations with both international and national academic and/or other research institutions. There were 77 labs that had international collaborations. For a majority of labs, upto 10 percent of their projects were international collaborations. There were 7 labs that were engaged in international academic collaborations for 10 percent to 20 percent of their total projects. With respect to national academic collaborations there were 27 labs for whom their share of national collaborations in total projects was more than 30 percent.

Figure 7.22 - Publication collaborations: International and National (%)
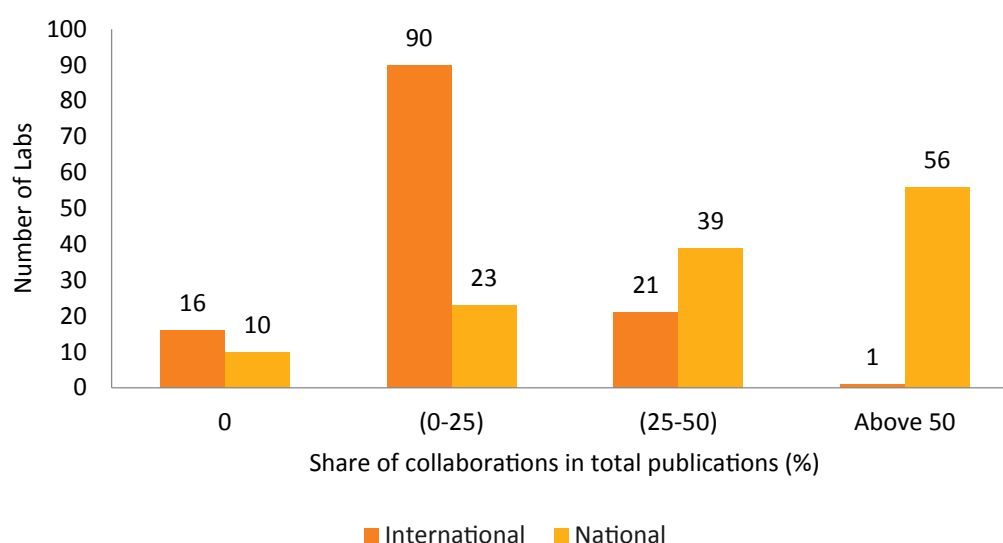
There were 123 labs out of 128 that had either international and/or national collaborations when it came to publications. For 90 labs, the share of international collaborations in their total publications was up to 25 percent.

With respect to the share of national collaborations in their total publications, 39 labs had a share between 25 percent to 50 percent, while 56 labs had a share of over 50 percent for national collaborations in their total publications.

Key takeaways: 02

- There were 43 labs that had greater than 60 publications in peer reviewed journals per 100 scientific staff. Of these, 41 labs belonged to major scientific agencies.

- By nature of the research being undertaken, many more labs should be engaged in producing commissioned technical reports. This would require a greater understanding from industry about the potential of these labs. Labs would also need to make a greater effort in showcasing their capabilities to industry.

- Several labs are not currently engaged in licensing out their patents. This is one area where labs could be provided assistance by their respective departments/ministries or industry associations in enabling wider access to the technologies being developed by the labs.

- There were 30 labs that introduced more than 2 new products and/or services per Rs 10 Cr of budgetary support. These were dominated by labs from ICAR.

- As with Basic labs, there is significant scope for increased collaborations not just with industry but also with other academic and/or research institutions. This would contribute towards possibly diversifying the sources of extramural funding away from mainly government sources.

- Increased collaborations on projects with academic institutions will also allow for use of the lab's facilities for students and researchers from the higher education sector.

Pillar 3: Organisational effectiveness

The indicators considered here look at the number of new research fields/innovations/services that have been introduced by a lab in each year under consideration, the share of permanent scientists and contractual researchers in the overall staff, indicators on governance that include whether the labs have ethics guidelines and policies in place, a sexual harassment mitigation cell etc., outside researchers supported, indicators on EDI and lastly the amount spent towards building internal capabilities of the staff.

- There were 127 labs that introduced at least one new research field/innovation/service on average every year for the period under consideration, of which 59 labs introduced 3 new research fields/innovations/services each year.

- Around 71 labs had a share of permanent scientists and contractual researchers in total staff that was greater than 50 percent.

- In terms of governance, the labs were following best practices for nearly all the parameters, except when it came to deployment of a software to track and

manage research projects through their lifecycle where just 70 percent of the labs had done so.

○ Around 72 percent of the total Applied R&D labs had a national and/or international accreditation of their lab procedures.

○ There were 84 labs that did not have an EDI cell, while the share of women in research staff was between 25 percent to 50 percent for around 64 labs.

○ There were 107 labs that spend less than 1 percent of their budget on training and skill upgradation of their staff

Sub-pillar 7: Mandate alignment

Figure 7.23 - New research fields/innovations/services introduced by the labs
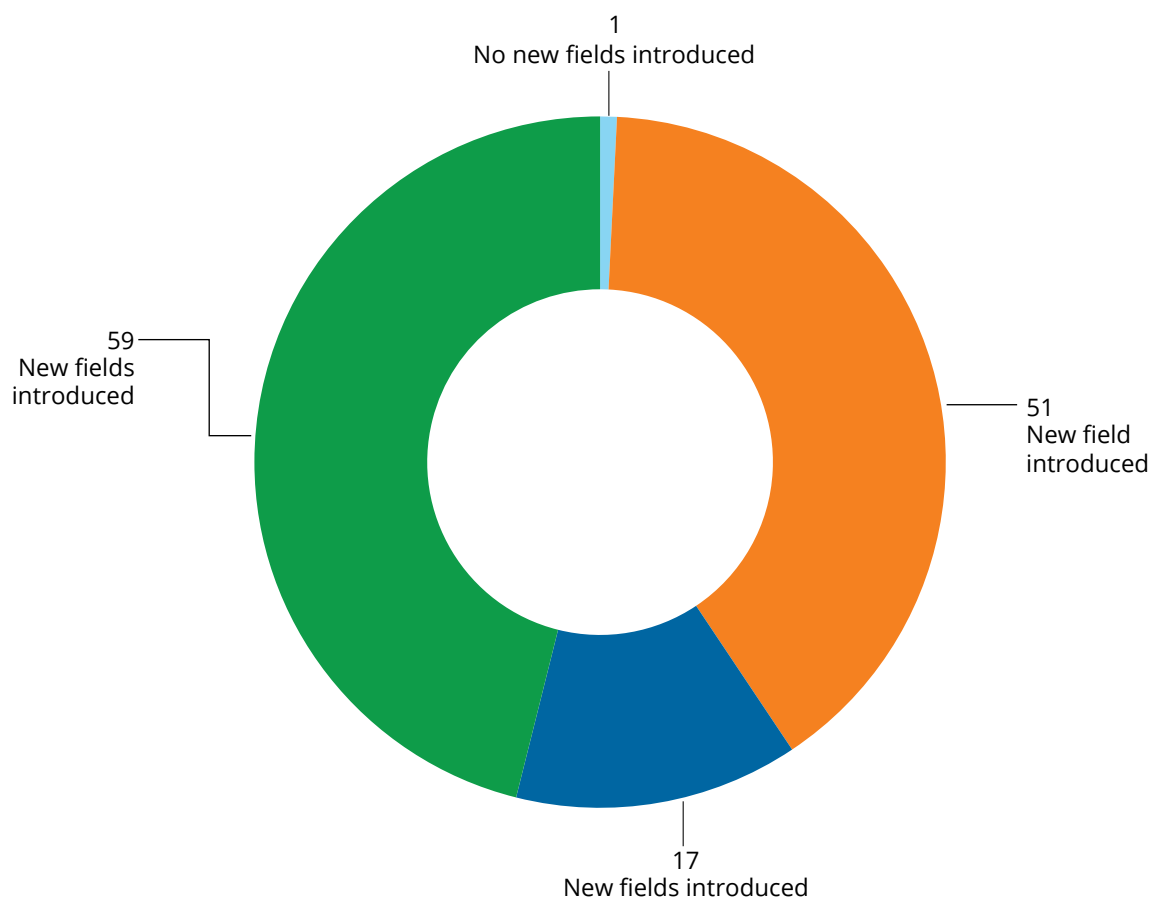
1
No new fields introduced

59
New fields
introduced

51
New field
introduced

17
New fields introduced

All labs have a scientific strategy in place to work towards their mandate. Nearly all the labs as part of their mandate have defined existing problems related to the social and economic situation of the nation and have been working towards solving these problems. Many of the labs have also seen the mission and vision for their research evolve over the past five years.

During the period under consideration, there were 59 labs that introduced 3 new research fields/innovations/ services in each year for the period under consideration, while 17 labs introduced at least 2 new fields/ innovations/services on average each year. There were 51 labs that introduced one new field/innovation/service on average each year. The impact of these new fields/ innovations/ services introduced would need to be evaluated separately by domain experts.

Sub-pillar 8: Resource management

Figure 7.24 - Share of permanent scientists and contractual researchers to overall staff (%)

Permanent scientists and contractual researchers to overall staff (%)
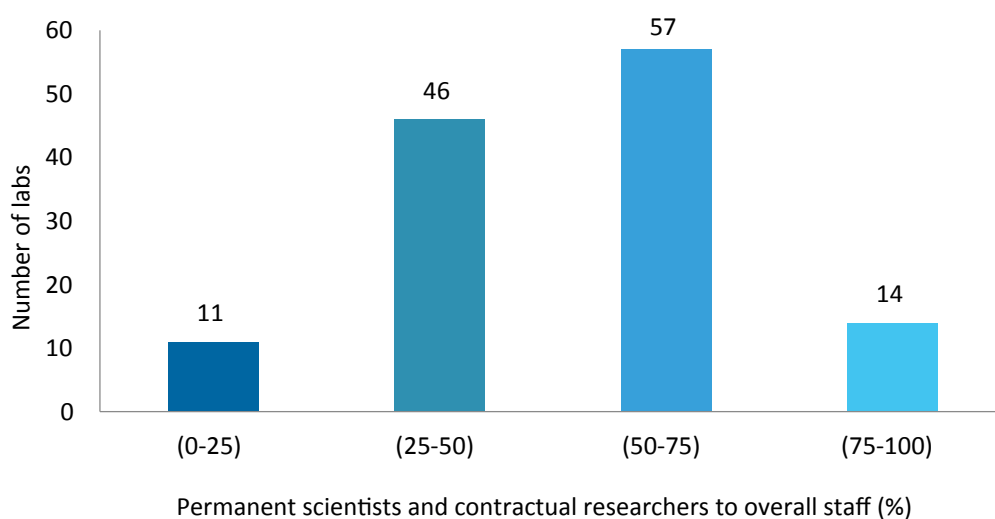
Of the 128 labs, there were 71 labs for whom the share of permanent scientists and contractual researchers in total staff was over 50 percent. There were 11 labs for whom the share of permanent scientists and contractual researchers was less than 25 percent.

For the 128 Applied R&D labs, the median value for R&D and S&T expenditure as a share of a lab's overall budget was close to 38 percent. The R&D and S&T related expenditure captures all research related expenditure including salaries paid to the researchers and travel costs related to research etc. and excludes administrative and other running costs. Nearly a third of labs that did report their R&D and S&T related expenditure as a share of the overall budget to be in excess of 75 percent.

Sub-pillar 9: Governance

A. Effectiveness of Management System

Table 7.1 - Effectiveness of Management System

	Share of labs that responded 'Yes' (%)
Does your organisation effectively communicate its objective and strategy to its staff?	100
Does your organisation have all requisite SOP/guidelines for its processes?	99
Are there initiatives in place to promote intra-organisational collaborations?	99
Has your organisation deployed any software system to track and manage research projects through its lifecycle, from conception to completion?	70
Does your organisation have necessary ethics guidelines and policies in place?	99
Does your organisation have a sexual harassment mitigation cell with requisite policies and procedures?	100
Does your organisation have a public grievance redressal cell?	97

Nearly all labs have the necessary effective management systems in place, such as guidelines for its processes, initiatives to promote intra-organisational collaborations, necessary ethics guidelines and policies, a sexual harassment mitigation policy as well as a public grievance redressal cell. However, one area that labs could improve on is in having a software system in place to track and manage their research projects. Currently only 70 percent of the Applied R&D labs had deployed a software system to track a project through its lifecycle.

B. Adherence to governance best practices

Table 7.2 - Adherence to governance best practices

	Share of labs that responded 'Yes' (%)
Does your organisation have national/international accreditation/certification for its lab procedure?	72
Does your organisation have transparent recruitment guidelines and processes in place?	100
Does your organisation's website capture details of your R&D facility, research manpower and mandatory disclosures?	100
Are website updates and maintenance carried out as per schedule?	99

With respect to governance related matters such as a transparent recruitment process, a website that provides details of the labs' R&D facility and other mandatory disclosures and regular maintenance of the website, all the Applied R&D labs do follow these governance related best practices. However, when it comes to having a national and/or international certification of its lab procedure, only 72 percent of the labs said they had this certification.

Figure 7.25 - Number of outside researchers per 100 scientific staff

Number of outside researchers per 100 scientific staff
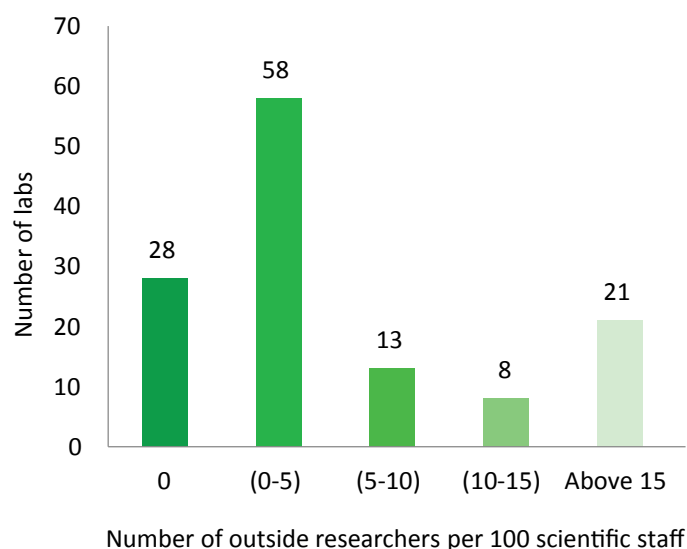
Of the 128 Applied R&D labs, there were 100 lab labs that supported outside researchers. Around 71 of these labs had upto 10 outside researchers per 100 scientific staff that were able to access the labs' facilities and were supported by the labs. As can be seen in the accompanying chart, there were 28 labs that did not have outside researchers accessing their facilities while 58 labs supported upto 5 researchers per 100 scientific staff. There were 21 labs that supported more than 15 outside researchers per 100 scientific staff.

Sub-pillar 10: Equity, diversity, and inclusion

Figure 7.26 - Provision of EDI cell and differently-abled friendly facilities

■ Number of labs that responded 'Yes'
■ Number of labs that responded 'No'
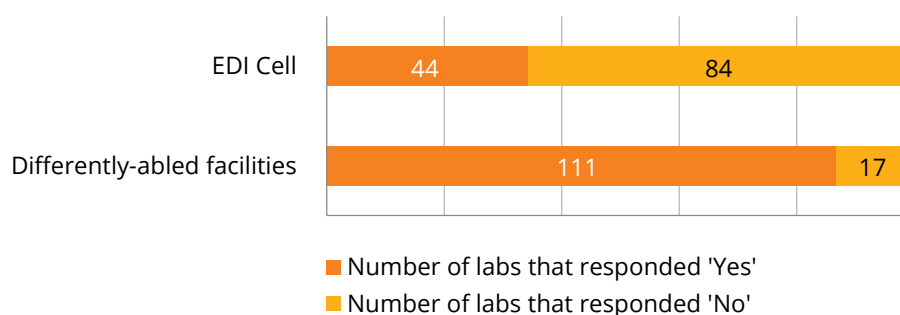
Just 44 of the 128 labs had an EDI cell while 111 labs had facilities that were differently-abled friendly. A majority of the labs would need to focus on improving their focus on EDI related matters by establishing a cell or committee dedicated to addressing any EDI related concerns.

Figure 7.27 - Share of young scientists and women scientists to the total scientific and research staff (%)
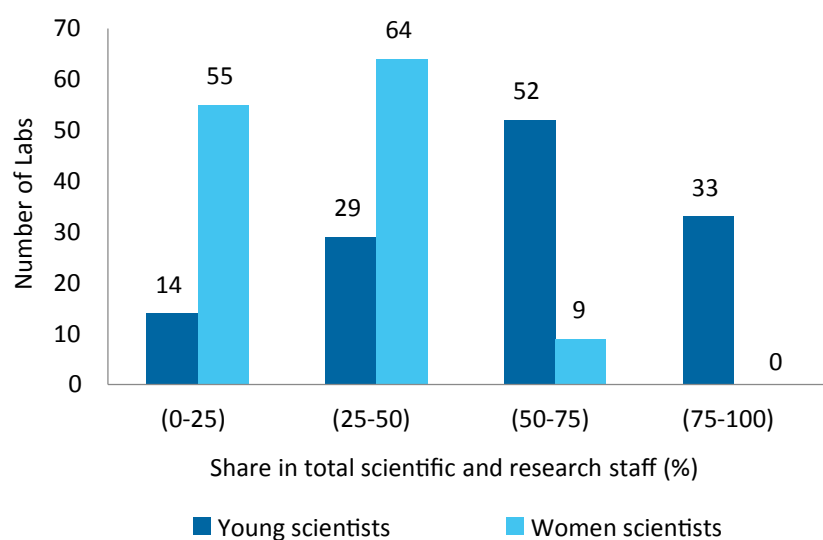
There were 64 labs for whom the share of women scientists as a share of total scientific and research staff was between 25 to 50 percent while 9 labs had a share between 50 to 75 percent. The 55 labs for whom the share of women scientists in total scientific and research staff was between 0 to 25 percent have scope to push for greater gender diversity among their research staff. With respect to young researchers (below the age of 40), 85 out of the 128 labs had a share of young researchers in total scientific and research staff that was greater than 50 percent.

Sub-pillar 11: Internal capacity building

Figure 7.28 - Share of total budget spent on training and skill up-gradation of the staff (%)
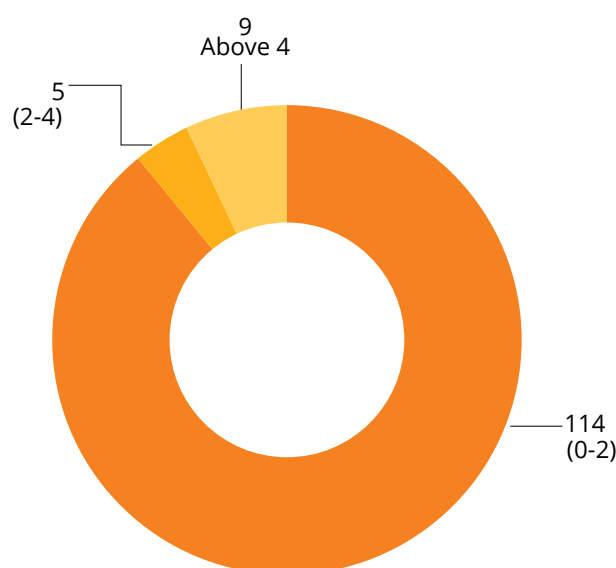
Of the 128 Applied R&D labs, 114 labs spend between 0 and 2 percent of their budget towards skills upgradation of their staff, while around 9 labs spend over 4 percent of their budget on skills upgradation of their staff. Over 80 percent of the labs were in fact found to spend less than 1 percent of their budget on training of their scientific staff and their administrative staff. Labs would need to focus on a holistic approach to R&D and S&T spending which would need to include increased allocation towards training of their staff, both research and administrative, to complement the R&D and other activities of the lab.

Key takeaways: 03

- There were 127 labs that introduced at least one new research field/innovation/service per year. It would require domain experts to evaluate the impact of these new research fields/innovations/services introduced.

- Of the 128 labs, there are 71 labs that have more than 50 percent of their staff as permanent and contract researchers. There is scope for many labs to increase the share of permanent and contract researchers in their total staff. Given the number of Science & Engineering PhDs being produced every year in India, efforts should be made to attract many more young researchers from this talent pool to contribute to the scientific endeavours of the publicly funded R&D labs.

- It would be important for all labs to consider deploying a software to track and monitor the progress of their projects. This would be a much needed and effective management tool to ensure greater impact of the projects being undertaken.

- Only 72 percent of the labs had any national and or international accreditation for their lab procedure. If engagement with industry as well as international collaborations are to increase, these effective management tools as well as necessary accreditations would be important practices to focus on for the balance labs.

- Establishing an EDI cell and increasing the share of women researchers in their total scientific staff would be important for labs to work towards for several labs.

- Labs would also need to invest in upgrading the skills of their research as well as administrative staff to complement the other research activities being undertaken. Currently it appears the expenditure on training and skills upgradation of their staff is very low. Of the 114 labs reported above that spend up to 2 percent of their budget on training, there are 107 labs that spend less than 1 percent of their budget on training and skill upgradation of their staff.

SERVICES R&D LABS

Services research by definition is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, directed to producing new products or processes or to improving existing products or processes. This chapter analyses the responses of laboratories that chose to categorise themselves as doing Services R&D. The TRL levels of the technologies developed by these laboratories were 6 or higher.

There were 55 labs that categorised themselves as Services R&D labs, of which there were 16 labs that were undertaking only services R&D while the remaining 39 labs were hybrid in nature i.e. they were also undertaking basic and/or applied R&D.

Of the 55 labs that categorised themselves as Services R&D labs, there were 17 CSIR labs and 13 ICAR labs, 4 labs from ICMR, 2 labs from DBT, 1 lab each from DST, MeitY, MoES and MoEFCC, and the remaining 15 labs from other central government ministries. Of the 16 labs that were undertaking only Services R&D, there were 9 from major scientific agencies and 7 were from other central government ministries. The average budget for the overall sample of 55 services research labs was around Rs 68 crores, while it was around Rs 56 crores for the 16 labs that were engaged in only services R&D. The average number of scientific staff for the sample of 55 labs was 141, while the average number of scientific staff for the 16 labs engaged only in Services R&D was 85.

Figure 8.1 - Sub-pillar wise average scores for Services R&D Labs

S.No.	Sub Pillar Name	Pillar Name
1	Contribution to SDGs and national programmes	Socio-economic impact
2	Employment generation and human resource development	
3	Scholarly research, development output and quality	Science, technology and innovation excellence
4	Development and innovation output and quality	
5	commercialisation of technologies and revenue generation	
6	Collaborative research	
7	Mandate alignment	
8	Resource management	
9	Governance	Organisational effectiveness
10	Equity, diversity, and inclusion	
11	Internal capacity building	

Figure 8.1 captures the average scores of the labs on the various sub-pillars. Labs have generally performed better on aspects of socio-economic impact as well as organisational effectiveness compared to science, technology and innovation (STI) excellence.

The labs on average have performed relatively better on sub-pillar 1 and sub-pillars 7 to 10 compared to the other pillars. The sub-pillars 2 to 6 cut across the socio-economic impact pillar and the STI excellence pillar. Figure 8.1 also provides the list of indicators covered under the various sub-pillars.

Figure 8.2 - Pillar wise scores for Services R&D Labs
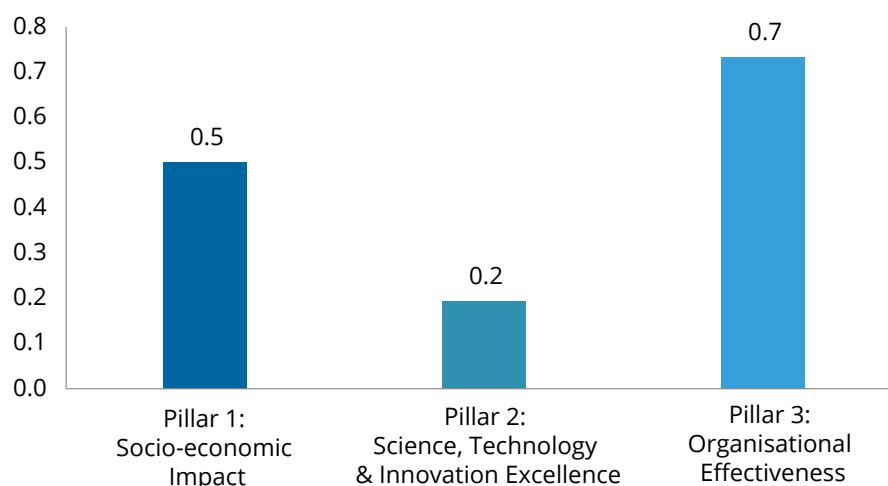
The pillar-wise average scores have been captured in Figure 8.2. The average score for the Services R&D labs was highest for the Organisational effectiveness pillar.

Based on the average performance of the labs on the different pillars, and given the nature of research being undertaken by these labs, some of the areas that the labs could perhaps focus on going forward include increased collaborations on projects with industry, perhaps even offering their services to international industry. This would not only contribute to the labs gaining recognition both nationally as well as internationally, but would further contribute to their earnings through consultancies. For some labs there may be opportunities to be engaged in providing skills development training while others could offer services in the preparation of technology documents etc.

The following section considers the performance of the labs focusing on around 40 key indicators that drive the performance in each of the sub-pillars mentioned in Figure 8.1, and thereby the overall pillar. The weights attached to these 40 indicators account for around 70 percent of the total framework. For comparability, where necessary the data has been scaled by either 100 scientific staff or Rs 10 Cr of budget spent.

Pillar 1: Socio-economic Impact

In this pillar on socio-economic impact, some of the key indicators that have been captured include the number of technologies (with TRL levels 6 and higher) targeted towards SDGs or national programmes, the targeted beneficiaries of the labs programmes, skill development programmes conducted, increase in scientific staff and incubation of startups. The data presented in the charts below are based on an average of the three years under consideration, namely FY2018, FY2019 and FY2020.

- ○ Of the 55 labs, there were 31 labs that had developed upto 10 technologies (targeting SDGs and/or national programmes) per hundred scientific staff while 15 labs had developed 10 or more technologies.

- ○ The primary beneficiaries of the output from the services labs are government departments followed by industry.

- ○ There were 8 labs that were not involved in conducting skill development programmes. At the higher end, there were 9 labs that conducted over 30 skill development programmes per hundred scientific staff.

- ○ Of the 55 labs, 32 labs saw an increase and 23 saw a decrease in the number of staff engaged in R&D.

- ○ Only 12 labs were providing incubation support to startups.

Sub-pillar 1: Contribution to SDGs and national programmes

Figure 8.3 - Technologies targeted towards SDGs & National Programmes (TRL 6 and higher)
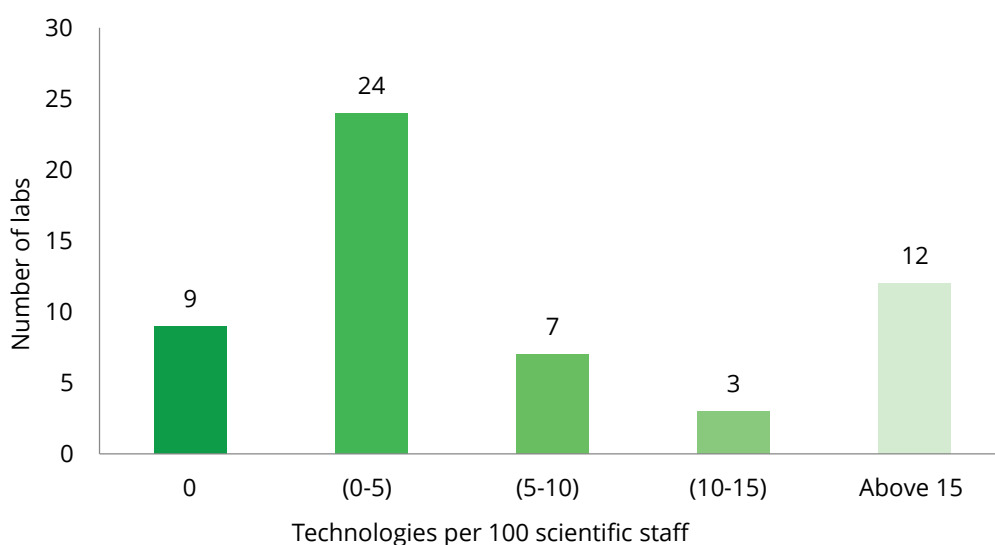
There were 9 labs that had classified themselves as Services R&D labs that had not developed any technologies with TRL 6 and higher (targeting SDGs and/ or national programmes). Of the remaining 46 labs, there were 31 labs that had developed up to 10 technologies per 100 scientific staff while 15 labs had developed more than 10 technologies per 100 scientific staff with TRL 6 and higher. The 15 labs with 10 or more technologies per hundred scientific staff included 6 labs from ICAR, 1 lab each from CSIR and MoES and the remaining 7 labs from other central government ministries.

Figure 8.4 - Beneficiaries of organisation's programmes

Beneficiaries of organisation's programmes
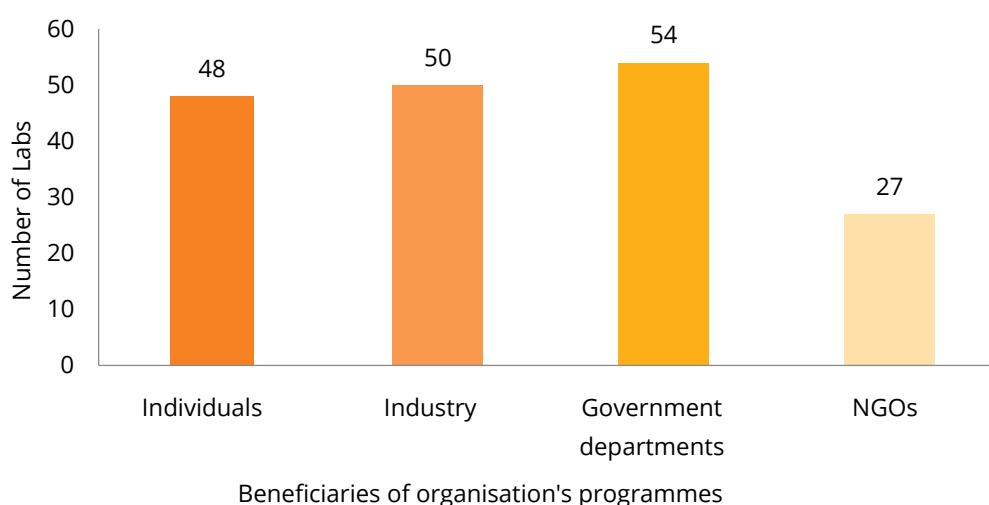
For Services R&D labs, most labs were targeting government departments through their research and programmes. Around 50 labs targeted industry through their research and programmes, just slightly higher than individuals who as a beneficiary group were targeted by 48 labs. Close to 50 percent of the labs targeted NGOs through their work.

Figure 8.5 - Number of skill development programmes conducted per 100 scientific staff

Skill development programmes conducted per 100 scientific staff
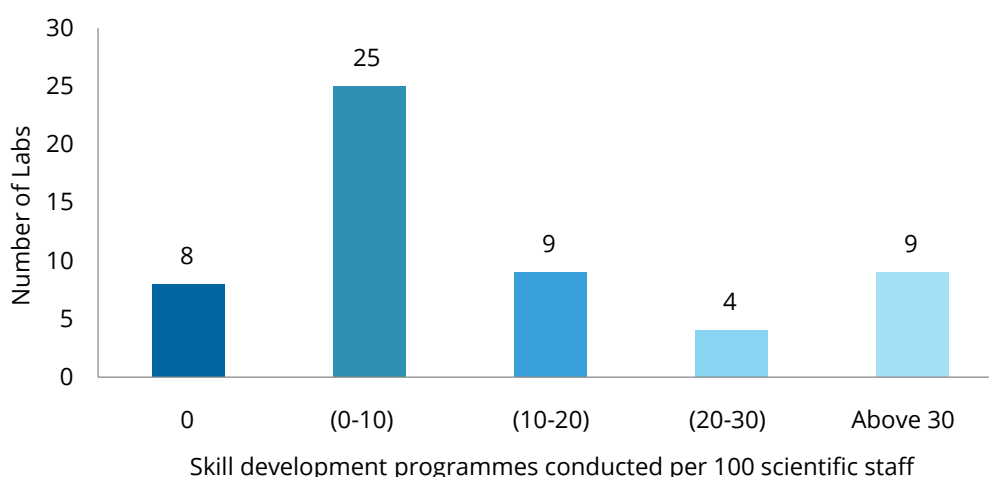
There were 8 labs that did not conduct any skill development programmes. Of the remaining 47 labs, there were 25 labs that conducted upto 10 skill development programmes per 100 scientific staff on average per year. At the higher end there were 9 labs that conducted over 30 skill development programmes per 100 scientific staff. The 9 labs at the higher end comprised 2 labs each from ICAR and CSIR, while the remaining 5 labs were from other central government ministries.

Sub-pillar 2: Employment generation and human resource development

Figure 8.6 - Number of labs that saw an increase/decrease in scientific staff

23
Number of labs that
saw a decrease in
scientific staff

32
Number of labs
that saw an
increase in scientific
staff

With respect to the change in number of staff engaged in R&D, there were 32 labs that saw an increase in scientific and research staff, while 23 labs had a decrease in scientific staff during the period under consideration.

Figure 8.7 - Percentage increase in staff engaged in R&D
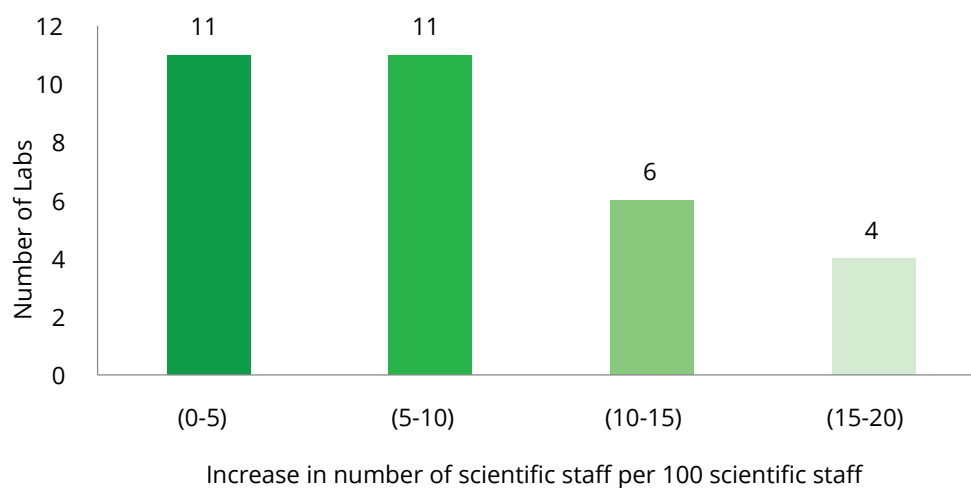
Of the 32 labs that saw an increase in scientific staff during the period under consideration, there were 11 labs that saw an increase between 5 to 10 scientific staff per hundred scientific staff while 10 labs saw an increase of 10 staff engaged in R&D per hundred scientific staff.

Figure 8.8 - Startups incubated

12
Number of labs that
incubated startups

43
Number of labs that did
not incubate startups
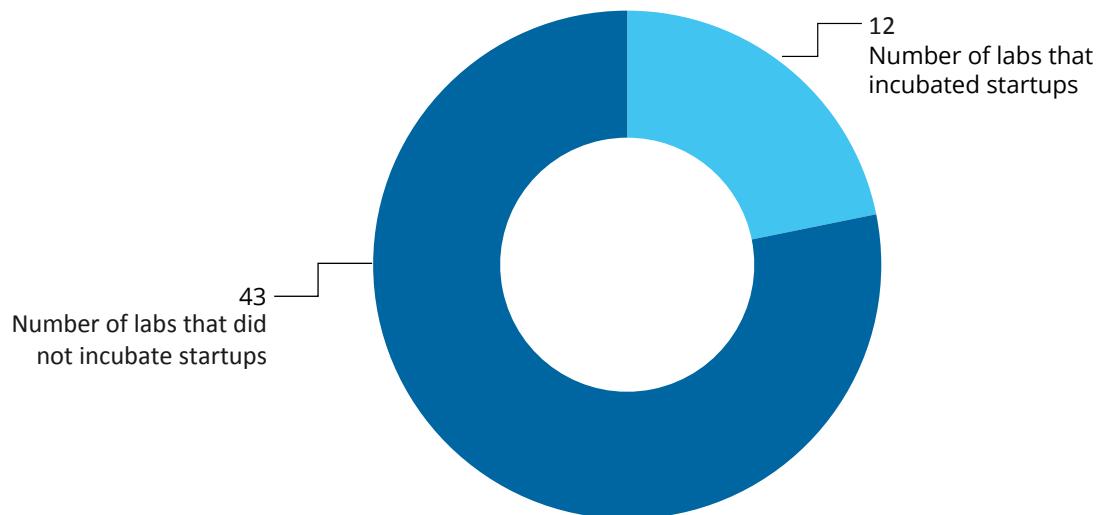
There were 43 labs undertaking Services R&D that were incubating startups while 12 labs did not provide any incubation support to startups.

Key takeaways: 01

- There were 15 labs that developed 10 or more technologies (targeting SDGs and/ or national programmes) per hundred scientific staff. These included 8 labs from major scientific agencies and the remaining 7 labs from other central government ministries.

- Currently only 50 percent of labs are targeting NGOs through their programmes, and more labs may wish to start engaging with NGOs for greater socio-economic impact.

- There were 9 labs that conducted over 30 skill development programmes per hundred scientific staff. Of these 9 labs, 5 were from other central government ministries.

- There were more Services R&D labs that saw an increase in scientific staff as compared to those that saw a decrease in staff during the period under consideration.

- More services labs should consider providing support to startups even if direct incubation support may not be feasible. There is significant scope for these labs to be engaged in multiple ways with the startup ecosystem, either through provision of consultancy and research support or through the use of their facilities where feasible.

Pillar 2: Science, technology and innovation excellence

For the pillar on STI excellence, the indicators captured below pertain to publication output, technology documents prepared,national and international recognitions technology transfer, contribution to policies and regulations, new services and/or products introduced, earnings from government and non-government sources, external funding received by the labs and collaborations on projects as well as publications.

- Around 20 percent of the labs had greater than 60 publications in peer reviewed journals per 100 scientific staff. Nearly a third of the labs were not involved in preparing any technology documents as part of the projects they were engaged in.

- While a majority of labs had received recognition for their work nationally, only 15 out of the 55 labs had received any international recognition.

- Around 39 out of the 55 labs had contributed to the formulation of policies, standards or regulations.

- There were 10 labs that had not introduced any new product or service in the three years under consideration while 29 labs had introduced up to 2 products per Rs 10 Cr of budget spent.

- A majority of the earnings for the labs came through consultancies, both from government and non-government sources. Of the 55 labs there were 37 labs that had earned upto Rs 1.5 Cr from government sources and 39 labs that had earned up to Rs 1.5 Cr from non-government sources per Rs 10Cr of budget spent.

- With respect to collaborations on projects with industry, there were 29 labs that had ongoing national collaborations while there were 8 labs that had ongoing international collaborations. There were many more collaborations on projects with academic institutions. Separately, 47 out of the 55 labs had either international and/or national collaborations when it came to publications.

Sub-pillar 3: Scholarly research, development output and quality

Figure 8.9 - Number of publications per 100 scientific staff
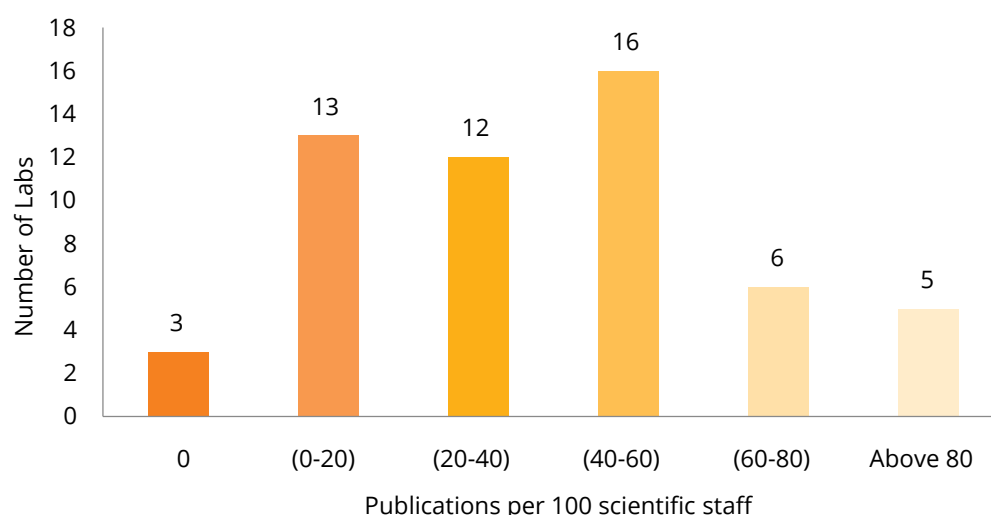
Of the 55 labs, there were 3 labs that had no publications. Around 41 of the remaining 52 labs had upto 60 publications per 100 scientific staff, while the remaining 11 labs had greater than 60 publications per 100 scientific staff. Of the 11 labs that had greater than 60 publications per 100 scientific staff, there were 7 CSIR labs, 1 lab each from ICMR, DBT and ICAR and 1 lab from another central government ministry.

Figure 8.10 - Number of technology documents prepared in preceding three years
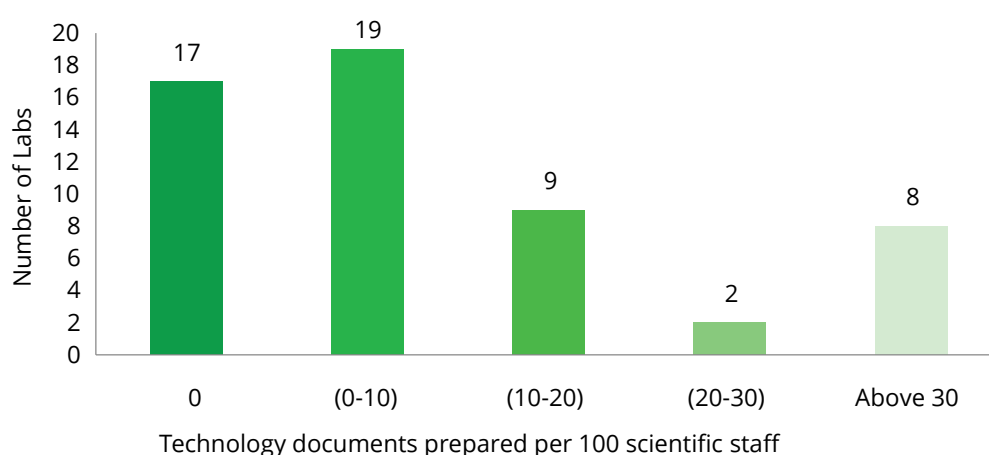
There were 17 labs that had not prepared any technology document as part of a project. Technology documents that were to have been considered here pertained to design, dossiers, regulatory submissions etc. Of the remaining 38 labs, around 28 of them produced up to 20 technology documents per 100 scientific staff while there were 8 labs that produced more than 30 technology documents per 100 scientific staff. These 8 labs at the higher end comprised 1 lab each from CSIR, DST and ICAR and 5 labs from other central government ministries.

Figure 8.11 - Number of Labs that received/not received recognition
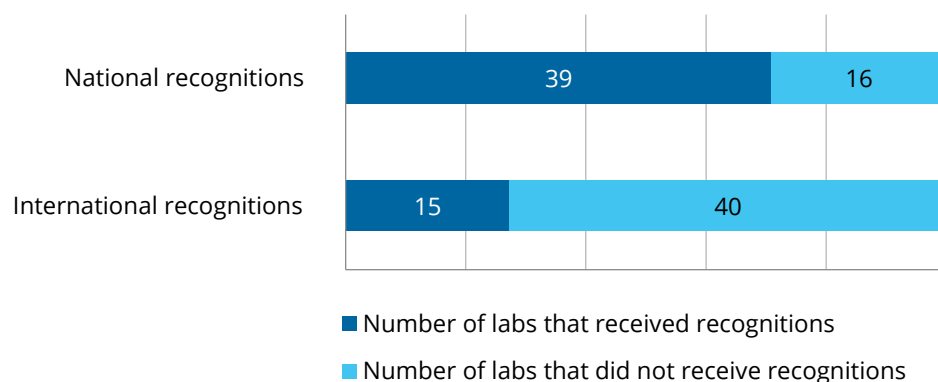
Of the 55 labs, there were 39 labs that had received national recognition/ accreditations, while 16 labs had not received any national recognition. Separately, there were 15 labs that had received international recognitions/ accreditations while 40 labs had not received any international recognition.

Sub-pillar 4: Development and innovation output and quality

Figure 8.12 - Technology transferred per 10 crore of budget spent
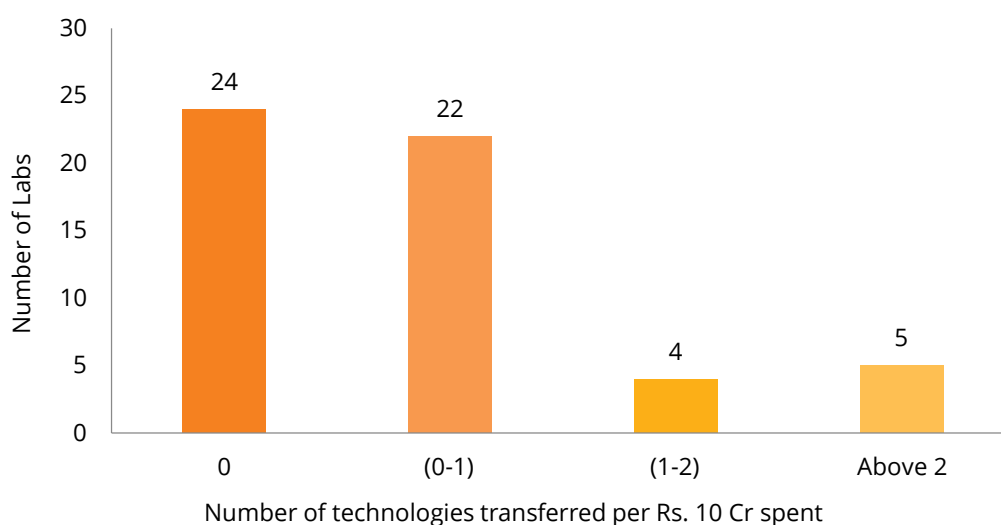
Twenty-four of the labs did not transfer any technologies during the period under consideration. Of the remaining 31 labs, there were 22 labs that transferred up 1 technology per Rs 10 Cr of budget spent. Of the total technologies transferred, around 42 percent were through licensing out of patents and other IPR.

Figure 8.13 - Number of labs that informed policies/standards/regulations

16
Number of labs that
informed policies/
standards/regulations

39
Number of labs that
did not inform policies/
standards/regulations
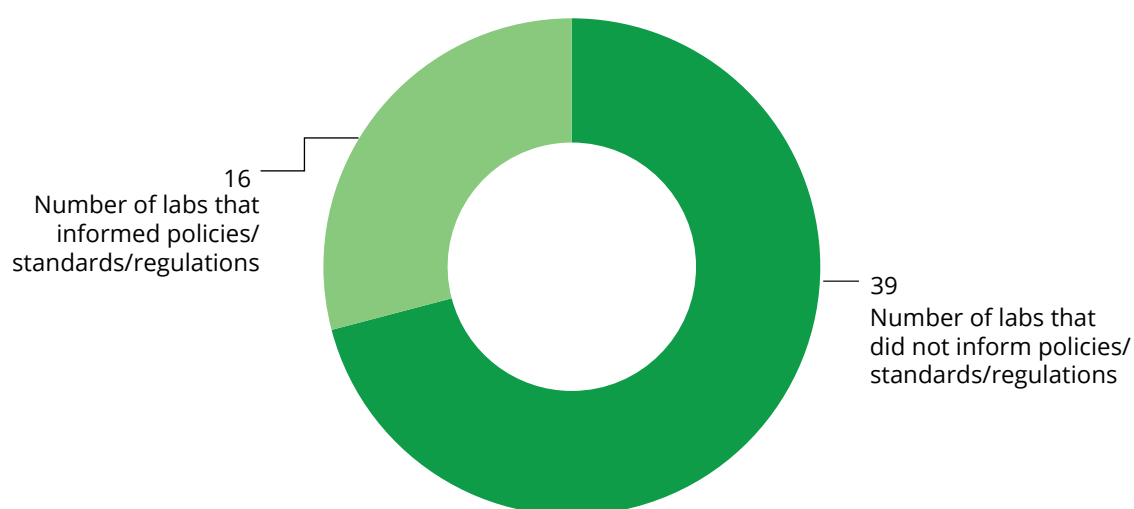
Of the 55 Services R&D labs, 39 labs through their scientific staff had contributed to informing policies or regulations.

Figure 8.14 - New services and/or products introduced per 10 crore of rupees spent
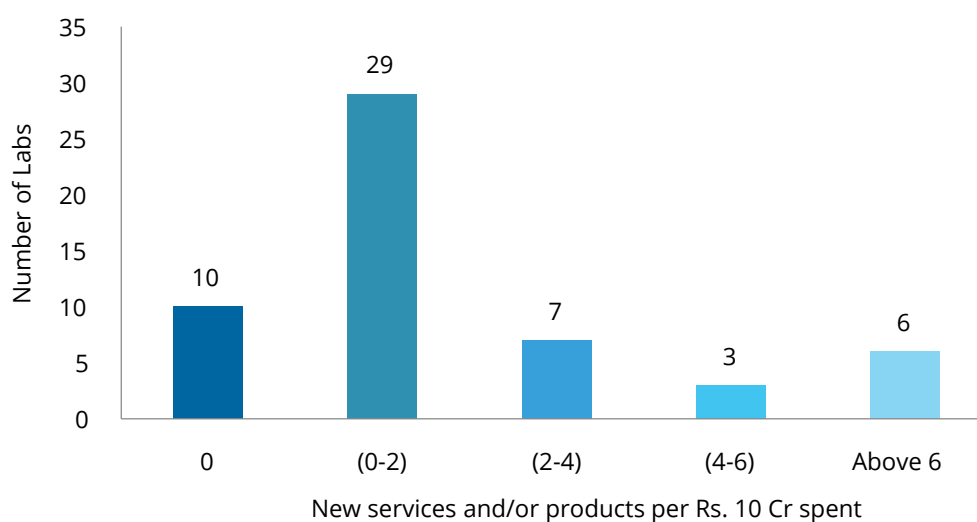
There were 10 labs that did not introduce a single new product or service in the period under consideration. There were 29 labs that introduced up to 2 new products and/or services per Rs.10 Crores of budgetary support while 16 labs introduced more than 2 new products and/or services per Rs.10 Crores of budgetary support. Of these 16 labs that introduced more than 2 new products and/or services per Rs 10 Cr of budgetary support, there were 7 labs from ICAR, 2 labs from CSIR and 7 labs from other central government ministries.

Sub-pillar 5: commercialisation of technologies and revenue generation

With respect to earnings from government and non-government sources, consultancies have been the major source for the Services R&D labs. As can be seen in the pie chart below, very little in earnings has come by way of technology transfer.

There were 9 labs that had no earnings from government sources while 6 labs had no earnings from non-government sources. There were 2 labs that did not have any earnings from either government or non-government sources. Of the 55 labs there were 37 labs that had earned upto Rs 1.5 Cr per Rs 10 Cr of budget spent from government sources and 39 labs that had earned up to Rs 1.5 Cr per Rs 10 Cr of budget spent from non-government sources. However for these labs that had earned upto Rs 1.5 Cr per Rs 10 Cr of budget spent, 22 labs had earned upto 0.5 Cr from both government and non-government sources.

At the higher end, there were 9 labs that had earnings of more than Rs 1.5 per Rs 10 Cr of budget spent from government sources and 10 labs that had these earnings from non-government sources. Of these labs at the higher end, there were 4 labs that had earnings from both government and non-government sources that were greater than Rs 1.5 Cr per Rs 10 Cr of budget spent. All the 4 labs were from other central government ministries.

Figure 8.15 - Earnings from government and non-government per 10 crore of rupees spent
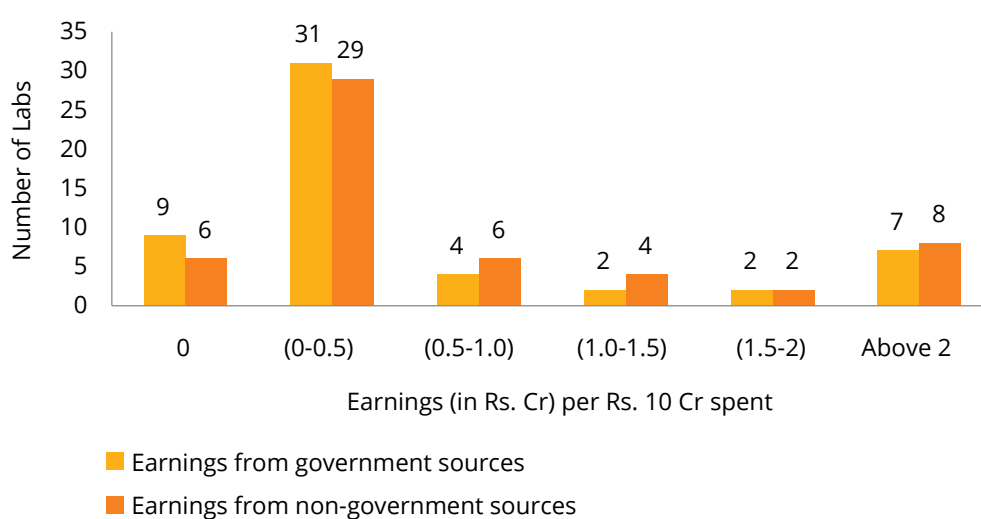
Figure 8.16 - Share of consultancy, training and technology transfer fees (%)

5%
Training fees

2%
Technology
transfer

93%
Consultancies fees
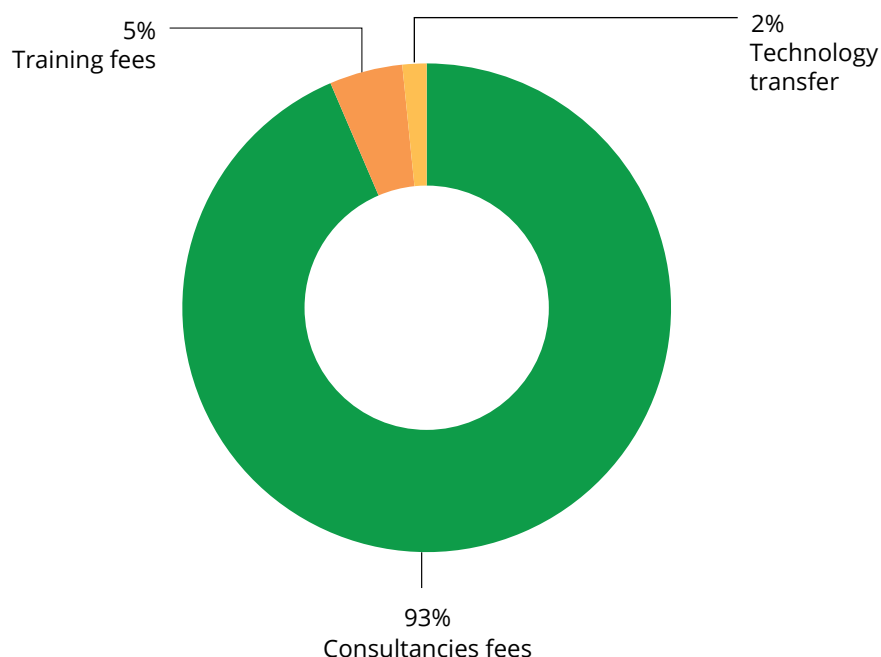
Sub-pillar 6: Collaborative research

Figure 8.17 - International and National industry project collaborations

International 8 / 47

National 29 / 26

■ Number of labs which have industry collaborations
■ Number of labs which do not have industry collaborations
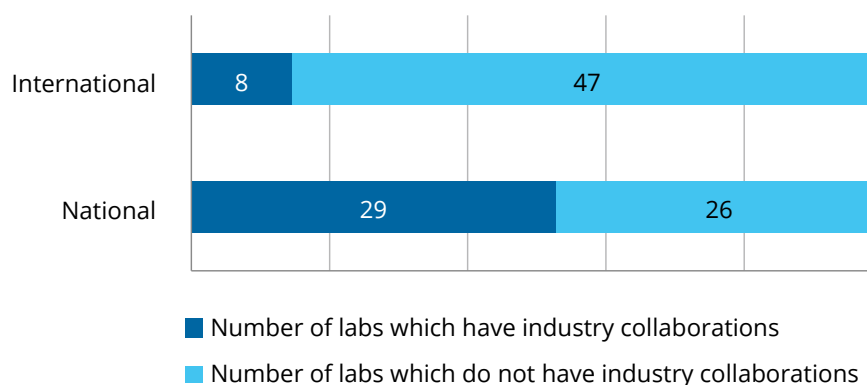
Just 8 labs were engaged in international collaborations on projects with industry during the period under consideration while 29 labs had ongoing national industry collaborations. There were 26 labs that had absolutely no national or international collaboration with industry while there were 6 labs that were engaged in both national and international industry collaborations. Of these 6 labs, there were 2 labs from CSIR, 1 lab each from DBT and MeitY and 2 labs from other central government ministries.

Figure 8.18 - Share of academic collaborations in projects executed (%)
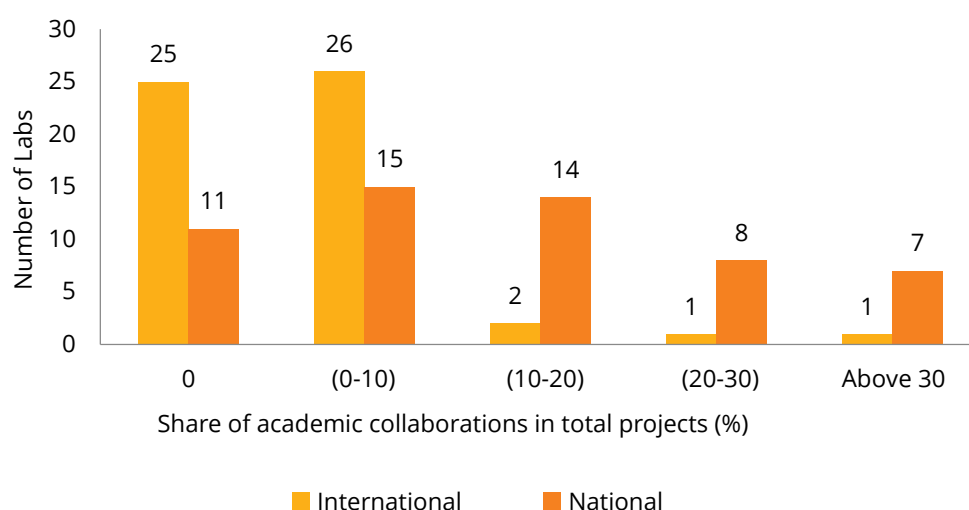
With respect to academic collaborations on projects, there were 30 labs that had ongoing international collaborations while 44 labs had ongoing national collaborations. There were 26 labs that had both international and national ongoing academic collaborations during the period under consideration. There were just 2 labs for whom the share of the international academic collaborations in their total projects was between 10 percent and 20 percent while there were 14 labs from whom the share of national academic collaborations in their total projects was between 10 percent and 20 percent. There were 7 labs for whom the share of national academic collaborations in their total projects was greater than 30 percent. Of these 7 labs, there were 3 labs from ICMR, 1 lab from CSIR and 3 labs from other central government ministries.

Figure 8.19 - Publication collaborations: International and National (%)
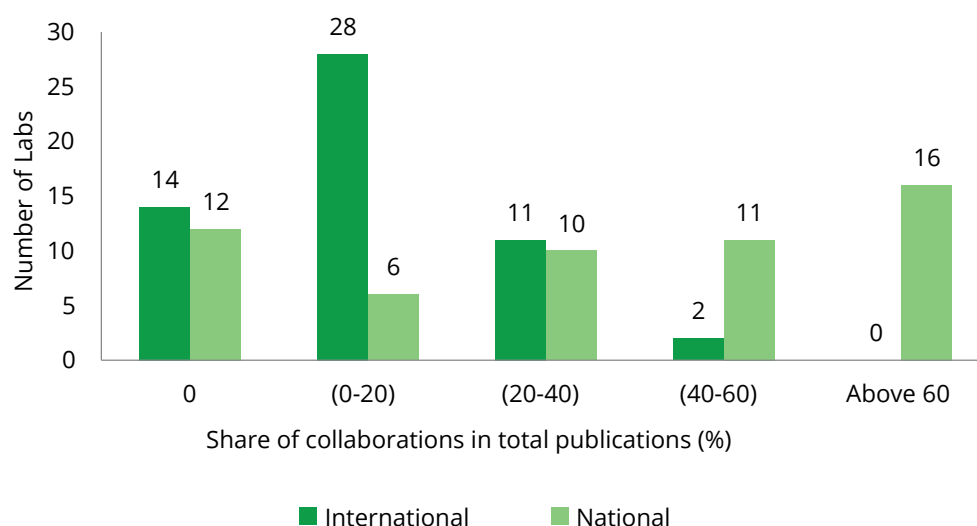
There were 47 labs out of 55 that had either international and/or national collaborations when it came to publications. For 28 labs, the share of international collaborations in their total publications was up to 20 percent, while 11 labs had a share of international collaborations in their total publications that was between 20 percent and 40 percent.

With respect to the share of national collaborations in their total publications, 10 labs had a share between 20 percent to 40 percent, while 27 labs had a share of over 40 percent for national collaborations in their total publications.

Key takeaways: 02

- There is significant scope for labs to provide services in the preparation of technology documents.

- While a majority of labs had received recognition for their work nationally, only 15 out of the 55 labs had received any international recognition. Increased recognition may help labs attract opportunities to provide more services to industry and partner institutions.

- Around 39 out of the 55 labs had contributed to the formulation of policies, standards or regulations. There is scope for labs to participate and increase their contribution to global policy and regulatory formulation.

- Out of the 55 labs, 10 labs did not introduce any new service or a product in the three reporting years while 29 labs introduced upto two new services or products. Given that these labs are performing services R&D, they may be encouraged to introduce more new services.

- With respect to earnings from government and non-government sources, consultancies have been the major source for the Services R&D labs.

- Increased collaborations with industry and offering services to international industry too, may contribute to increased earnings through consultancies.

Pillar 3: Organisational effectiveness

The indicators considered here look at the number of new research fields/innovations/services that have been introduced by a lab in each year under consideration, the share of permanent scientists and contractual researchers in the overall staff, indicators on effective management systems and adherence to governance best practices indicators on EDI and the amount spent towards building internal capabilities of the staff.

- There were 54 labs that introduced at least one new research field/innovation/ service on average every year for the period under consideration, of which 29 labs introduced 3 new research fields/innovations/services each year.

- There were 26 labs that had a share of permanent scientists and contractual researchers in total staff greater than 50 percent while there were 9 labs for whom the share of permanent scientists and contractual researchers was less than 25 percent.

> ○ In terms of governance, the labs were following best practices for nearly all the parameters, except when it came to deployment of a software to track and manage research projects through their lifecycle where just 65 percent of the labs had done so.
>
> ○ There were 19 labs that did not support any outside researchers.
>
> ○ A majority of labs did not have an EDI cell, while 23 labs had a share of women researchers in their total scientific staff that was between 0 and 25 percent.
>
> ○ There were 46 out of the 55 labs that spent less than one percent of their budget on the skills upgradation of their staff.

Sub-pillar 7: Mandate alignment

Figure 8.21 - New research fields/innovations/services introduced by the labs
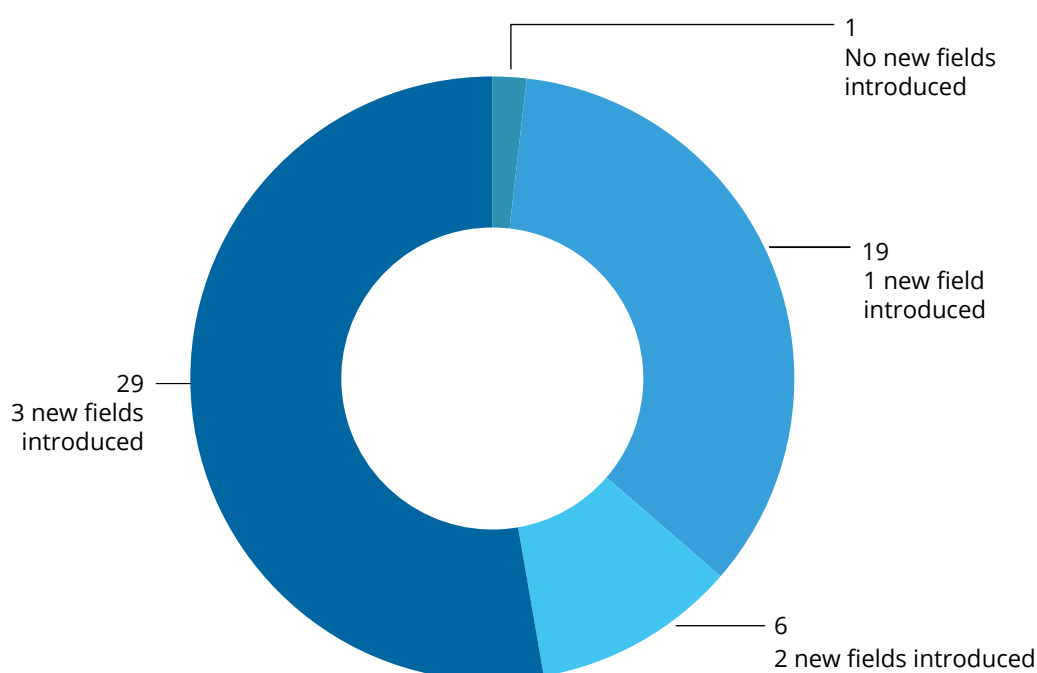
All labs have a scientific strategy in place to work towards their mandate. Nearly all the labs as part of their mandate have defined existing problems related to the social and economic situation of the nation and have been working towards solving these problems. Many of the labs have also seen the mission and vision for their research evolve over the past five years.

Of the 55 labs that had classified themselves as undertaking Services R&D, there were 29 labs that introduced 3 new research fields/innovations/ services in each year for the period under consideration, while 6 labs introduced at least 2 new fields/ innovations/services on average each year. There were 19 labs that introduced one new field/innovation/service on average each year. The new fields/innovations/services introduced by these labs would need to be evaluated separately by domain experts.

Sub-pillar 8: Resource Management

Figure 8.22 - Share of permanent scientists and contractual researchers to overall staff (%)

Permanent scientists and contractual researchers to overall staff (%)
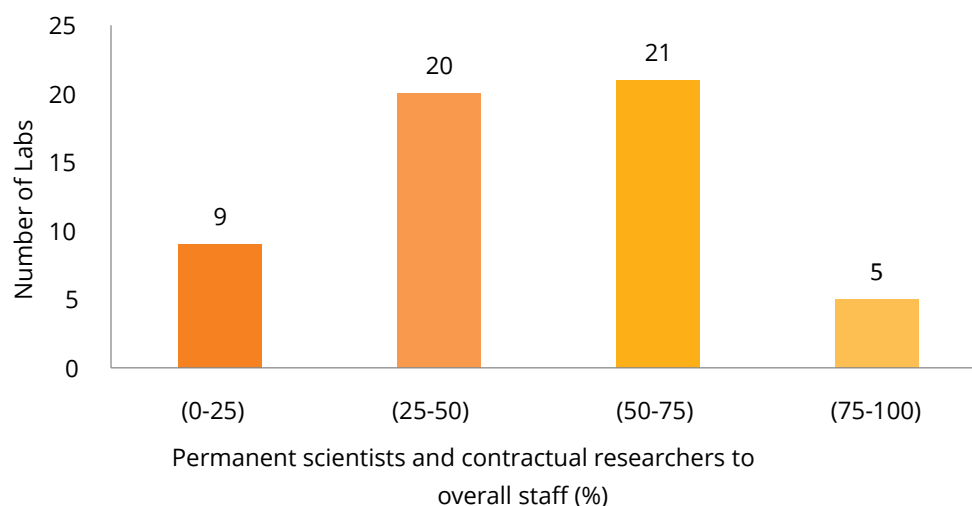
Of the 55 Services R&D labs, 26 labs had a share of permanent scientists and contractual researchers in total staff that was over 50 percent. There were 9 labs for whom the share of permanent scientists and contractual researchers was less than 25 percent.

Sub-pillar 9: Governance

A. Effectiveness of Management System

Table 8.1 - Effectiveness of Management System

Question	Share of labs that responded 'Yes' (%)
Does your organisation effectively communicate its objective and strategy to its staff?	100
Does your organisation have all requisite SOP/guidelines for its processes?	98
Are there initiatives in place to promote intra-organisational collaborations?	100
Has your organisation deployed any software system to track and manage research projects through its lifecycle, from conception to completion?	65
Does your organisation have necessary ethics guidelines and policies in place?	100
Does your organisation have a sexual harassment mitigation cell with requisite policies and procedures?	98
Does your organisation have a public grievance redressal cell?	95

Currently only 65 percent of the Services R&D labs have deployed a software system to track a project through its lifecycle. This is one area that labs could improve on. With respect to other management systems, such as guidelines for its processes, initiatives to promote intra-organisational collaborations, necessary ethics guidelines and policies, a sexual harassment mitigation policy as well as a public grievance redressal cell, nearly all labs have the necessary effective systems in place.

B. Adherence to governance best practices

Table 8.2 - Adherence to governance best practices

Question	Share of labs that responded 'Yes' (%)
Does your organisation have national/international accreditation/ certification for its lab procedure?	75
Does your organisation have transparent recruitment guidelines and processes in place?	100
Does your organisation's website capture details of your R&D facility, research manpower and mandatory disclosures?	100
Are website updates and maintenance carried out as per schedule?	98

On governance related best practices 75 percent of the labs had a national and/or international certification of their lab procedure. With respect to the other practices such as a transparent recruitment process, a website that provides details of the labs' R&D facility and other mandatory disclosures and regular maintenance of the website, the labs do follow these governance related best practices.

Figure 8.23 - Number of outside researchers per 100 scientific staff
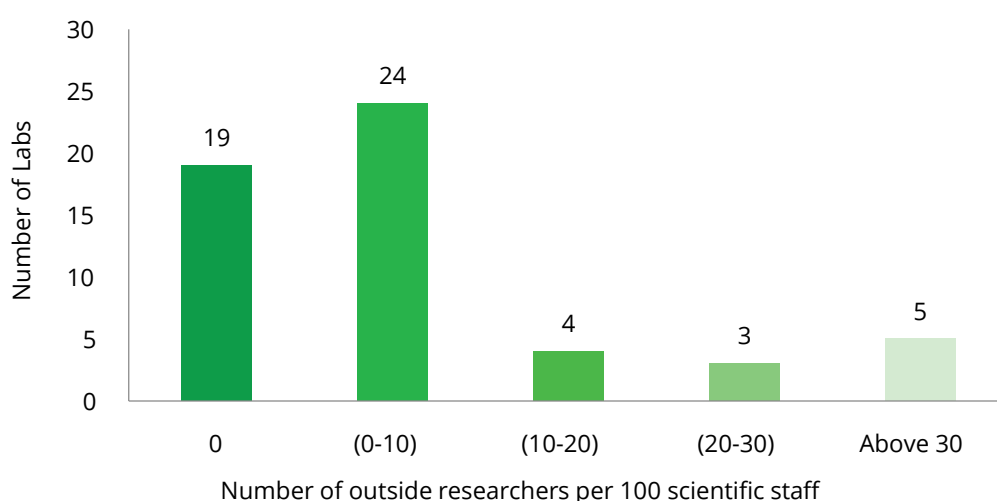
Of the 55 Services R&D labs, there were 36 lab labs that supported outside researchers. Around 24 of these labs had upto 10 outside researchers per 100 scientific staff that were able to access the labs' facilities and were supported by the labs.

Sub-pillar 10: Equity, diversity, and inclusion

Figure 8.24 - Provisions of EDI cell and differently-abled friendly facilities
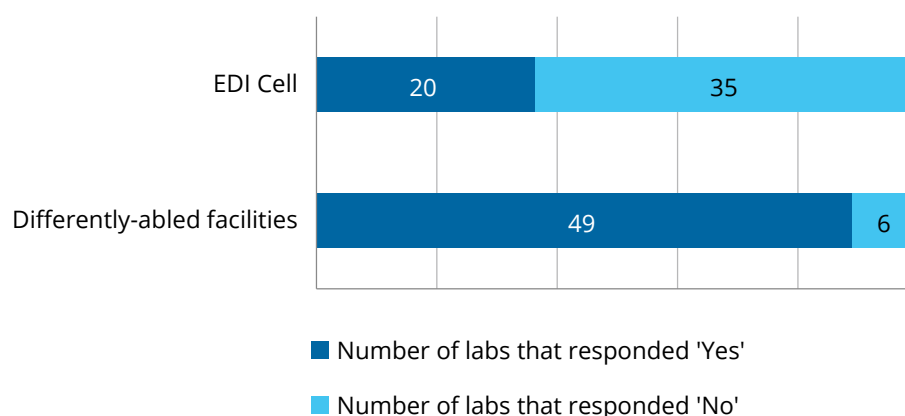
Not all labs had an EDI cell. There were just 20 labs that said they had an EDI cell while 49 labs said their labs were differently-abled friendly. It would be important for labs to continue to strive towards greater inclusion by having a requisite cell or committee in place to address concerns around EDI.

Figure 8.25 - Share of young scientists and women scientists to the total scientific and research staff (%)
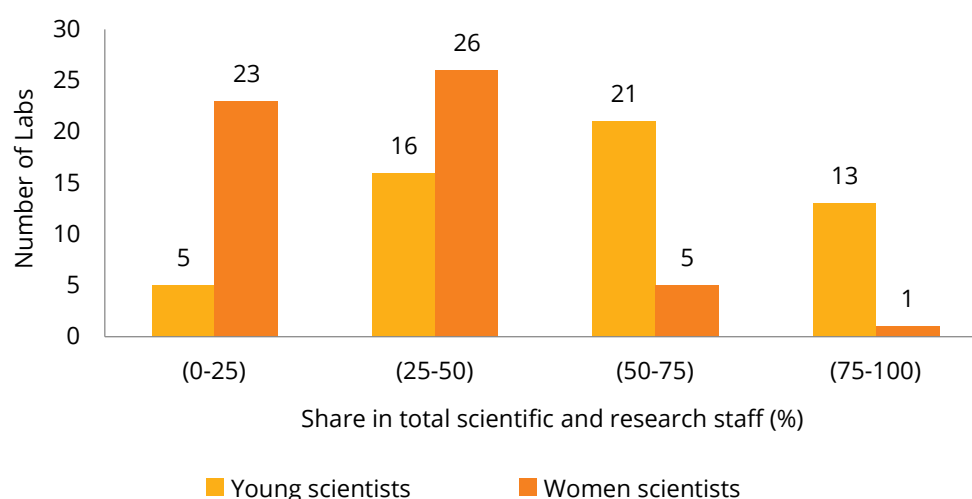
There were 26 labs for whom the share of women scientists as a share of total scientific and research staff was between 25 to 50 percent while only 5 labs had a share between 50 to 75 percent. The 23 labs for whom the share of women scientists in total scientific and research staff is between 0 to 25 percent have scope to push for greater gender diversity among their research staff. With respect to young researchers (below the age of 40), 34 out of the 55 labs had a share of young researchers in total scientific and research staff that was greater than 50 percent.

Sub-pillar 11: Internal capacity building

Figure 8.26 - Share of the total budget spent on training and skill up-gradation of the staff (%)
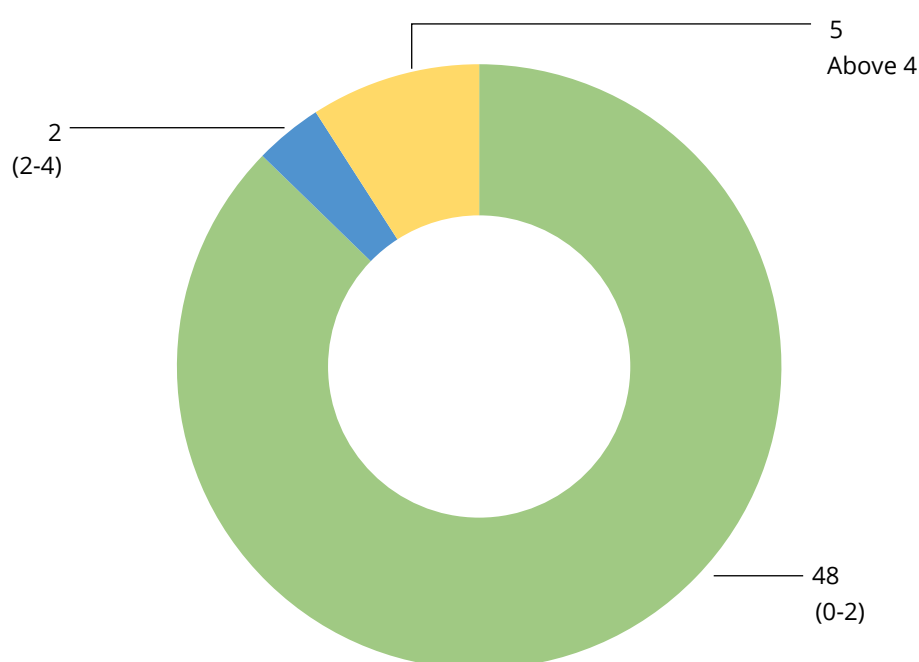
Most labs have allocated very little of their budget towards training of their staff, both research as well as administrative staff. Of the 55 services R&D labs, 48 labs spend between 0 and 2 percent of their budget towards skills upgradation of their staff. In fact 46 of these 48 labs spend less than 1 percent of their budget on training.

Increased expenditure on training and skill upgradation would help complement the R&D and other activities of the labs. Labs should consider a holistic approach to their R&D and S&T expenditure that sees increased allocation towards training of their scientific and research staff as well as administrative staff to support their scientific and research staff.

Key takeaways: 03

- It would be important for domain experts to review the new research field/innovation/service introduced by the labs. Nearly all the labs were seen to introduce at least one new research field/innovation/service per year.

- There were 9 labs for whom the share of permanent scientists and contractual researchers was less than 25 percent. Of the 9 labs, there were 5 labs that were from other central ministries.

- It would be important for all labs to consider deploying a software to track and monitor the progress of their projects. This would be a much needed and effective management tool to ensure greater impact of the projects being undertaken.

- Supporting outside researchers as a service should be encouraged by labs undertaking Services R&D. This would also ensure greater opportunities for researchers from industry, startups and even academic institutions to make use of the facilities and research support of the lab.

- It would be important for services R&D labs to establish a cell or committee that ensures that an EDI policy is adhered to.

- There were 46 out of the 55 labs that spent less than one percent of their budget on the skills upgradation of their staff. Increased spending on staff would possibly allow labs to undertake a variety of services apart from research activities such as the staff in turn conducting a variety of skills development programmes for the wider population etc.

Chapter 9

RECOMMENDATIONS

In this chapter, we look at the learnings from the study and dwell on the recommendations which shall serve as a roadmap towards improving the outcomes from public funded R&D labs.

These recommendations are grouped into four main categories:

9.1.   Strengthening engagement with the national STI ecosystem

9.2.   Strengthening organisational capabilities

9.3.   Improving contribution towards the societal benefits

9.4.   Providing home grown solutions to global development challenges

Table 9 - Overview of policy focused recommendations

Category	Recommendations
9.1. Strengthening engagement with the national STI ecosystem	9.1.1. Expand research collaborations with industry
	9.1.2. Explore the establishment of mechanisms based on proven international models of collaboration for translational research
	9.1.3. Improve cross-linkages between labs and HEIs
	9.1.4. Increase engagement with startups
	9.1.5. Increase collaboration with other labs in the country

Category	Recommendations
9.2. Strengthening organisational capabilities	9.2.1. Mandate certification and accreditation for lab procedures
	9.2.2. Improve technology commercialisation
	9.2.3. Improve facilitation of Intellectual Property Rights (IPRs)
	9.2.4. Create a centralised repository of technologies
	9.2.5. Deploy standardised digital infrastructure and platforms
	9.2.6. Create in-house capability for data collation
	9.2.7. Improve capacity building and career development of lab scientists
	9.2.8. Improve Equity, diversity and inclusion (EDI)
	9.2.9. Improve participation of women in research
9.3. Improving contribution towards societal benefits	9.3.1. Align research and development with national needs and priorities
	9.3.2. Improve access to scientific resources by educational institutions
	9.3.3. Engage civil society in dissemination of knowledge
	9.3.4. Create a portal to improve engagement with students
	9.3.5. Share findings from the research to inform policy
9.4. Increasing scientific and policy contribution to global development challenges	9.4.1. Increase international project collaborations
	9.4.2. Enhance extramural funding to boost the STI ecosystem
	9.4.3. Explore collaborations for technology promotion
	9.4.4. Contribution to global regulation and policy

9.1 Strengthening engagement with the national STI ecosystem

These recommendations explore various ways in which a R&D lab can strengthen existing linkages with other stakeholders in the national STI ecosystem such as industry, higher education institutions (HEIs), startups and other R&D labs. All public R&D labs are a precious repository of accumulated knowledge and dissemination of knowledge from these labs to the wider ecosystem will have several far-reaching positive impact.

Towards the aforesaid objectives, the recommendations are as follows:

9.1.1. Expand research collaborations with industry

The current study reveals that only 37 percent of the respondent national labs were engaged in collaborations with the industry in India, and around 8 percent of labs were collaborating with industry overseas. While labs work on the creation of new knowledge, industry plays

an important role in bringing these innovations to market. Thus, a close cooperation between labs and industry is essential to increase the real-world impact of research through innovations in new products, processes and services.

The following ways to expand these collaborations are recommended:

○ The CII proposal on ADMIRE (Advanced Mission-mode Innovation and Research) programme is under way and has been recommended at various forums including in PM-STIAC and in the new STI policy. It is proposed that the respective line ministries provide direct R&D grants to industry on risk-sharing mode through a competitive bidding process against technology development challenges floated by them from time to time. While 50% of the project cost would be borne by the government as grant-in-aid support to the industry, the balance 50% would be mobilized by the industry. The Government grants will be utilized by selected industry to co-invest in the entire value chain of R&D, technology development, technology acquisition, IP filing, contract research, and technology commercialisation. The industry would also be encouraged to submit proposals for the development of frontier and critical technologies. The projects will be jointly undertaken by an industry and a national laboratory or cluster of laboratories.

○ Labs can also consider creating a portfolio of technologies (on the lines of a pitch-book) to be made available on an online platform for their easy access by the interested stakeholders.

○ Greater participation of labs in PPP Initiatives like SERB-CII Prime Minister's Fellowship Scheme for Doctoral Research: The Prime Minister's Fellowship Scheme for Doctoral Research is a public-private partnership (PPP) initiative of Science & Engineering Research Board (SERB), an autonomous body under the Department of Science and Technology (DST), Government of India (https://www.primeministerfellowshipscheme.in/). This scheme is aimed at encouraging young, talented, enthusiastic, and result-oriented scholars to take up industry-relevant research. Under this scheme, full-time PhD scholars get funded partly by the government and partly by a company that works closely with the candidate on the research project.

Therefore, all scientific labs may be encouraged to nominate a few PhD scholars every year to undertake SERB-CII PM Fellowship with industry partners for industry relevant research. Fortnightly / monthly sensitization sessions for the faculty and PhD students across all the scientific research institutions to create awareness and encourage participation may be organised.

○ Labs can conduct industry regular 'Open days' wherein the industry (local firms or SMEs) can interact with the scientific staff and understand and explore different ways of collaborating with labs.

9.1.2. Explore the establishment of mechanisms based on proven international models of collaboration for translational research

Technology Catapults in UK, Max Planck Institutes and Fraunhofer Institutes in Germany and a few others from technologically advanced countries like USA, Israel and Korea work on mechanisms that help bridge the "valleys of death" between the basic and pilot stages, and pilot and commercialisation stages respectively. Institutions of similar mechanisms can be

explored for sharing of funding and other resources between industry, government and the research institutions in the following lines:

○ Dedicated Translational Research Centres (TRCs) can be established in each research institute or critical economic zones of the country and sized according to the research output.

○ These centres must employ professional technologists to work full time and have a cell that facilitates all external interactions with interested parties and supply chain partners.

○ These may be funded jointly with an industry consortium and government. CSR funds available with the industry could be utilized for the purpose.

○ Industry associations could be entrusted with the job of establishing one or two such Translational Research Centres in two different regions of the country to start with.

9.1.3. Improve cross-linkages between labs and HEIs

Higher Education Institutes (HEIs) and research laboratories are the two knowledge creating pillars of the universal STI ecosystem. Improving linkages between HEIs and labs can lead to better research at universities, fostering research talent as well as harnessing the strengths of HEIs and labs towards better outcomes. The following steps are recommended in that direction:

○ Improve mobility through secondment of faculty members from HEIs to the research labs and the scientists from the labs being sent to HEIs for academic courses and collaborative research

○ Taking up research projects under the joint guidance of scientists from the labs and professors from the academic institutions.

○ Create new mechanisms for cross-cutting learning through peer-to-peer networks among researchers and academics

○ Explore collaborations on joint long-term research projects/programmes with a focus on outcomes. For example, through the City Knowledge Clusters that are being developed through the office of the PSA, a research lab and HEI can work on long-term projects (especially in the areas of health, water, and climate change) that have positive outcomes. for that city and the successful project can then be taken up for scale

9.1.4. Increase engagement with startups

Startups play a very critical role in the innovation ecosystem across the world. The study reveals that in the year 2019-20 there were just 35 labs that were providing incubation support to startups. Startups have the agility and ability to harness new technologies and bring them to the market. However, startups by themselves do not always have access to scientific know-how and they depend on the lab infrastructure for synthesis, analysis and testing.

Labs play a very important role of nurturing the startups by engaging with the startup ecosystem through incubators, accelerators and spin offs. This applies to all labs, especially when research breaks new ground and offers newer commercial opportunities which are better availed by the startups. For example, there are now a number of satellite imagery

startups that work with the Ministry of Agriculture to improve crop yields, predict weather patterns through a well-established mechanism. Similarly, startups from incubators connected with labs such as the Venture Centre or C-Camp have all been at the forefront of technological solutions deployed during the pandemic. There is room to grow this engagement further either through increasing the reach of existing schemes such as PRAYAS, or identifying potential linkages with programmes through Startup India.

9.1.5. Increase collaboration with other labs in the country

Communication and collaboration with other labs in the ecosystem would ensure sharing of knowledge especially for interdisciplinary subjects, optimization of precious resources, and best practices.

To improve such collaborative avenues, the following steps are recommended:

○ A top-down approach should be adopted for funding collaborative projects among various labs.

○ Creation of an online platform as a repository for the current research interests, current and future projects by all the laboratories for the identification of collaboration opportunities. Periodic interactive meetings among the labs would also help in that direction.

○ Necessary steps should be taken for sharing of resources such as database and bibliographic subscriptions. Another important aspect would be conducting research in a specific laboratory by utilizing high value equipment by other labs.

9.2. Strengthening organisational capabilities

These recommendations elucidate on various ways in which a R&D lab can improve its own capacity and capabilities towards better outputs and outcomes by optimizing human resources, resource allocation and infrastructure. These recommendations include:

9.2.1. Mandate certification and accreditation for lab procedures

Accreditation of the laboratory especially its procedures and practices assumes critical importance as adherence to certain protocols and practices will make a lab perform as per defined and required standards. Around one third of the participating labs mentioned that they do not have national or international accreditation/certification for the lab procedures. The labs should not only be mandated to attain these certifications but should also be provided with centralised help to better understand the procedure for attaining these certifications. This will only help the labs in fetching more projects with industry and international organisations and also bring in more extramural funding for their research.

Towards that direction, the following are recommended:

○ Workshops can be organised to train these labs on the importance of certification and accreditation, the nationally and internationally accepted standards for these certifications and the procedure to be followed in order to get accredited and certified for their lab procedures.

○ Government may consider making the accreditation mandatory for the research labs after a certain period (say, 2-3 years) which will merit their eligibility for any extramural funding.

9.2.2. Improve technology commercialisation

It has been experienced worldwide that successful technology transfer and commercialisation are the cornerstones of the innovation ecosystem. New knowledge creation and their applications add to a nation's wealth creation and employment generation, which are key economic indicators. Not only would it help labs sustain their research with revenue from technology commercialisation but industry too stands to benefit immensely from such new business avenues.

The present study reveals that there has been an increase in international technology transfers from14 in 2017-18 to 20 in 2019-20, but a gradual decline in the numbers of domestic technology transfers, from 636 in 2017-18 to 613 in 2019-20.

It may be noted that the labs are engaged in developing technologies across different TRL levels depending on the nature of the R&D being performed. It has been observed that most of the laboratories develop technologies with lower TRLs (Services labs offer technologies with higher TRLs). However, the industry desires TRLs 7 or 8 for their early commercialisation. Timely support in terms of funding and IPR would help in the translational and commercialisation of more technologies.

In that direction, following are the recommendations:

○ Allocation of certain financial resources to all labs which can be mobilized additionally for translational research, pilot plant trials and scale-up. of the technologies developed in the labs for their improvement in 'Technology Readiness Levels'.

○ Create or use ready resources to conduct workshops for PIs or similar stakeholders in labs on technology transfers and its potential benefits

○ Labs can also strengthen connections with grassroots organisations for better knowledge flow

○ Harnessing the network of technology transfer offices across the country and the cluster of startups and SME ecosystems to improve technology commercialisation

○ Industry associations in partnership with various labs/institutions can host Technology Workshops/ Webinars for creating awareness among the industry in India and abroad about the commercialization/ licensing of already developed technologies - this would give a boost to earnings from external sources.

9.2.3. Improve facilitation of Intellectual Property Rights (IPRs)

IPRs are an important source of information on innovation. They are considered as one of the best indicators of a lab's innovative capabilities and great measure of their intellectual assets. It was observed that not many labs filed and published IPRs such as patents, copyrights, trademarks etc. The patent filings have slowed from 657 in 2017-18 to around 605 in 2019-20.

Towards improving the situation, the following are recommended:

○ In order to encourage the scientists to enhance the volume and value of IPRs and subsequent technology transfer, it may be useful to have provisions for definitive career interventions like financial incentives (cash awards, additional increments etc.) and preferential promotional rules

○ Specialized workshops can help the labs know more about the importance of creating an IP, procedure for filing IPRs and at the same time, protect their intellectual property once published.

○ The creation of an IPR Management Cell in all institutions as a Nodal Centre of Excellence in IP matters will further help enhance the volume and value of IPRs and subsequent technology transfer. The Centre would primarily be responsible for awareness promotion on all aspects related to IPR among the lab scientists and other technical staff. The Centre shall create and evolve appropriate systems to capture and assess the IP generated in the labs. The Centre will also mobilize and influence IP related issues and concerns. The Centre will manage the patent portfolio both defensively and aggressively, as a business activity. The Centre shall evaluate the publication vs IP protection for every scientific output.

9.2.4. Create a centralised repository of technologies

It has been observed from the current study that the total number of technologies that were being or had been developed with TRLs 0 to 4 and targeting SDGs and national programmes was 666 in 2019-20 compared to 597 in 2017-18. This compares to 1192 technologies that were developed or were being developed with TRLs 5 and higher targeting SDGs and national programmes in 2019-20 versus 1088 technologies in 2017-18.

Towards improved commercialisation of technologies developed by the labs, the recommendations are as follows:

○ The Government of India may create a specialized agency for funding and nurturing of translational research

○ Allocation of specific budget for technology promotions and outreach will be useful for dissemination

○ Creating a website providing centralised repository of technologies and patents, available for commercialisation or licensing available with each of its labs with participation from all Ministries can become a one-stop point for all stakeholders - for example, industry associations can publicize this website/ repository to its entire network of Indian industries, International MoU Partners, Agencies, Embassies for further dissemination.

○ Thematic e-newsletters can be published and widely disseminated to enable technology transfer and partnerships

9.2.5. Deploy standardised digital infrastructure and platforms

The study reveals that 61 percent of the participating labs use a standardised MIS for tracking projects and other related metrics. While there are some systems in place and certain labs do use sophisticated systems, an increased effort towards effective knowledge management

and knowledge sharing can lead to better research output and outcomes. For example, having standardised MIS platforms can help in better utilization of resources across labs and planning. Moreover, collecting and sharing such data in a consistent format can increase the research collaboration from different locations and disciplines towards solving complex problems.

9.2.6. Create In-house capability for data collation

It has been observed that the entire questionnaire requires inputs from various sources and not from a single office. Keeping in mind the upcoming initiatives on data architecture as well the overall increasing importance of data in decision making, it is recommended that labs should have a dedicated data officer. Steps should be taken to build in-house capability for centralised information collection. This would help in improved decision-making.

It is essential that the central information cell has a deep, overall understanding of the organisation's work and is well placed to coordinate with different departments within the organisation to collect data internally as per the requirements of the framework. For example, for the purpose of this study, the nodal officer had to coordinate with the finance department to gather data related to funding and earnings or with the administrative department to gather data related to the total scientific staff present at the organisation. Similarly, for gathering IPR related data, the nodal officer had to coordinate with more than one department within the organisation.

9.2.7. Improve capacity building and career development of lab scientists

It has been observed that the labs have good and important management practices in place. Around 95 percent of labs said they had incentives in place to promote talent while around 98 percent of labs had a structured career progression plan in place for their scientific staff. But the spending on training of their staff remains close to or less than 1 percent of the total budget for most labs. In this fast-changing world of new knowledge creation, it is important to invest considerable efforts and resources on the training needs of the scientists, both for their personal growth and also to intensify the intellectual asset of the organisation.

Such voids in training needs may be addressed by the following:

○ Time bound structured training programmes and workshops both at the national and international level (Existing practices for IAS officials may be a pointer in the direction)

○ Deputation of more scientists to foreign universities and research laboratories

○ Encouraging sabbaticals, and exchange programmes and collaborations with other national and international research institutions.

9.2.8. Improve Equity, Diversity, and Inclusion (EDI)

Various studies have established that a diverse and inclusive workforce helps in fostering innovation. Institutional commitment to the principles of equity, diversity and inclusion are reflected through the presence of institutional mechanisms such as the presence of EDI cells and other related policies. Only 35 percent labs have EDI cells, and it is recommended that EDI should be given due recognition and importance by all the labs. Labs should ensure setting up of EDI cells, followed by discussions on how to improve the same at lab level.

9.2.9. Improve participation by women in research

The importance of gender equality in STEM is already well studied and documented. Structured interventions in increasing the number of women researchers in scientific agencies help create a skilled talent pool as highlighted by different studies such as UNESCO's work on girls' and women's education in STEM.

The present study reveals that the median value for the participation of women researchers across 193 labs surveyed stands at 30 percent in 2019-20. Even though most labs have some women staff, there is scope to improve the gender ratio in labs.

Towards that direction, the following steps are recommended:

- There should be a clear roadmap for every lab to have a certain percentage of women scientists in the next 5 years. To facilitate this, preferential and focused recruitment strategies must be in place for women scientists.

- A clear set of rules that enable and promote lateral entry of women scientists should be in place.

- Various institutional programmes should be initiated as part of the Institute's gender diversification policies. For example, On International Women's Day, every year, women scientists could be bestowed with special merit-cum-performance awards (preferably, with a cash incentive). 'Women only' recruitment drive should be organised as part of celebrations for International Women's Day for interviews and recruitment.

9.3. Improving contribution towards societal benefits

These recommendations focus on the crucial role of scientific institutions and their activities towards the benefits of Indian Society. The study findings establish that all R&D labs are committed towards reaching out to the Indian society in general for improving the social dividends by their research products. These recommendations explore how the current contributions can be enhanced to tackle different challenges faced by Indian society ranging from poverty, malnutrition, access to water, healthcare and education improving equity for all.

These include:

9.3.1. Align research and development with national needs and priorities

Establishing effective linkages with societal outcomes and development indicators is critical for a robust research and innovation ecosystem. The survey reveals that most labs have been engaging with the Sustainable Development Goals at the institutional level. Based on the current lab responses, most targeted SDGs include 'Good health and well-being' and 'Industry, innovation and infrastructure' whereas very few labs focus on goals such as 'Sustainable cities and communities', 'Affordable and clean energy', and 'Partnerships for the goals. An increased awareness level for the researchers could motivate them further as they associate their work with a larger benefit to society.

The following interventions would be quite effective in this regard:

- Workshops on SDGs may be organised for increased awareness among the researchers

○ Activities concerning SDGs could be assessed as an integral part of career development programmes.

○ The mandate of the labs can be revisited to check for their alignment with the national needs and priorities. This was also suggested in the NITI Aayog report as a potential area of exploration to improve the impact on society

○ Many labs of the country are involved in public services be it cyclone management, weather forecasting, Himalayan disasters, climate changes and so on. It is of utmost importance that such societal programmes are well captured, documented and adequately encouraged. Scientists must be appropriately rewarded for undertaking research based on national interests.

○ A national level exercise may be undertaken for the identification of specific national needs. This should also focus on developing lab capacities and strengthening the labs towards catering to the identified and unmet societal needs.

9.3.2. Improve access to scientific resources by educational institutes

Labs have certain outreach activities such as 'open days' to encourage interest in science among younger generations. The following interventions may be effective in addition to these ongoing activities:

○ Introduce/ increase lecture demonstrations for local university staff and young scholars to improve scientific temper and create potential avenues for newer collaborations

○ Introduce specialized degree / diploma / certificate programmes to students from HEIs based on the area of research focused on by the lab, to facilitate cross learning and to introduce research methods and technologies to the students at an early stage

○ Sharing of resources of the labs such as sophisticated and advanced synthetic/analytical equipment with state universities and other HEIs will also be useful in building long term scientific capacity, especially in smaller cities where educational institutions may not have access to such resources

9.3.3. Engage civil society in dissemination of knowledge

The pivotal role of research institutions in improving economic conditions and well-being of our nation is well recognised. The study reveals that a very high percentage (94%) of 193 labs surveyed catered to government departments while 77% and 48% percent of them worked for the industry and NGOs respectively.

The role of civil society in 'last-mile delivery of research' i.e. adoption and awareness of indigenously developed technologies and solutions is not so well explored. Increasing the involvement of NGOs in the dissemination of research has the potential to make science inclusive as well as create better knowledge flows for labs in terms of how their research links to ground realities.

9.3.4. Create a portal to improve engagement with students

A common portal, facilitated by the ministries, can be introduced to disseminate the research findings and learnings from the labs. The portal can act as a go-to resource for students from

different schools and universities across the country. The portal can display information for all upcoming scientific activities which students could participate in. The portal can also act as a medium to engage with researchers who would be willing to enrol as interns as well as to get support for their research.

9.3.5. Share findings from the research to inform policy

It has been inferred from the study that only 50 percent of labs have contributed towards national policies, regulations or standards, either by the participation of their scientists in various committees or their work having direct contribution to a policy or regulation etc. While most of the labs perform laudable research in their respective areas, it would greatly benefit the society and the country if their research findings are also taken into consideration while a policy, regulation or standard is being formulated.

9.4 Increasing scientific and policy contribution to global development challenges

India has been a partner of choice for many countries for the development of new scientific knowledge and collaborations. India can play a bigger role on the global stage and expand her growth ambitions through STI. A number of indigenously developed scientific solutions has the potential to tackle and mitigate global challenges like climate change, food security, green energy solutions, healthcare, etc.

The following set of recommendations explore improved engagements of Indian STI ecosystem on a global scale:

9.4.1. Increase International project collaborations

The study establishes that around 8 percent of labs were collaborating with industry overseas and 1.2% of the labs opted for in 2019-20. Some research activities such as new seed varieties, low-cost earthquake building technology developed by India have already been disseminated and deployed internationally. To increase international project collaborations, appropriate interventions in terms of international fellowships and travel awards for researchers by the government agencies may be further strengthened.

9.4.2. Enhance extramural funding to boost the STI ecosystem

The study infers that over 90 percent of funding to labs comes from government sources. Improving external funding through international and other non-government channels will be important for sustained outcomes from research. It is recommended that the labs explore access to extramural funds through collaborative R&D with industry and other international agencies.

9.4.3. Explore collaborations for technology promotion

Many developing countries are eager to collaborate with India for research and technology partnerships and this must be leveraged fully besides strengthening existing partnerships with countries like the US, Japan, UK, Russia, Korea and Israel.

This can be achieved through:

○ Scientists from labs such as CSIR should be engaged on a regular basis in presenting technologies to Indian and international industries, universities, business councils, international industry associations, embassies etc. at technology promotion platforms and outreach events.

○ The research institutions may also connect with industry associations to conduct thematic sessions on focused technologies

9.4.4. Contribution to global regulation and policy

Just 17 percent of the labs contributed to international policies. Greater participation in the global arena through sharing of research findings and contributions to global policies and regulations would benefit the world at large.

Chapter 10
WAY FORWARD

There are several ways in which this framework may be used by the policymakers. For instance, it may be used to showcase the contribution of public funded R&D labs to India's innovation ecosystem. The framework can also contribute to national and international statistics on public R&D in India, show future pathways for R&D labs to strengthen their own capabilities, and help further R&D labs' contribution for societal benefit and increase their engagement with the wider world.

As this is the first time a complex exercise like this has been undertaken, there are several learnings that have emerged that can be used for the benefit of future exercises.

The following section suggests specific recommendations for the framework and future rounds of this study.

It was noted in the NITI Aayog report that the framework may be revisited and re-evaluated after one round of implementation. This report has laid a strong foundation for this exercise and provided below are the recommendations that may help strengthen the framework as well as the processes of data collection and validation.

The recommendations fall into two main categories:

10.1.   Formation of an expert committee to re-evaluate the framework

10.2.   Institutionalizing the process of data collection and validation.

Table 10 - Overview of recommendations for future rounds of the study

Category	Recommendations
10.1. Formation of an expert committee to re-evaluate the framework	10.1.1. Clearly defining the eligibility criteria and what constitutes a public R&D lab
	10.1.2. Revisit weights of the pillars and sub-pillars to better reflect the role of public R&D labs
	10.1.3. Revisit applicability of certain indicators and refining current indicators
	10.1.4. Assistance from domain experts to evaluate qualitative responses
10.2. Institutionalizing the process of data collection and validation	10.2.1. Support of line ministries/departments in data collection
	10.2.2. Aligning the data reported in the annual reports with the indicators in the framework
	10.2.3. Embedding the data templates in portal to help in efficient validation of the data reported by the labs

10.1. Formation of an expert committee to re-evaluate the framework

The formation of an expert committee is a vital step towards enhancing the value of this framework and ensuring alignment with national priorities. The Office of the PSA provided direction and became an umbrella to bring together members from different ministries and departments for the first round of this study, hence we recommend that the expert committee be formed under the aegis of the Office of the PSA. The proposed committee may follow the same pattern as that of the Working Group constituted for this study wherein there is representation from different ministries and departments in the form of Directors of various R&D institutions and presence of experts such as those from NITI Aayog and statisticians from renowned institutions.

As the framework used in this study was modified only to improve the understanding of the respondent, there are several learnings in the form of feedback on indicators and applicability of indicators that may be considered by the expert committee when re-evaluating the framework.

These are highlighted below as recommendations:

10.1.1. Clearly defining the eligibility criteria and what constitutes a public R&D lab

All 606 R&D institutions listed in the Directory of R&D Institutions 2018 published by the Department of Science and Technology (DST) were approached for the first round of this study. The list includes all types of organisations like R&D labs, educational institutions, some of which do not perform R&D as implied in the framework.

During the course of the study, several institutions in DST list such as institutions under DPIIT and the Department of Animal Husbandry and Dairying stated that they were not eligible for

the exercise as their mandate was training oriented, or the framework did not apply to the R&D performed by them. Moreover, strategic labs under the Department of Atomic Energy, Department of Space and such others did not participate in this exercise, although some strategic labs had participated in the pilot studies and were a part of the Working Group as well. The strategic labs mentioned that the framework did not reflect the output and outcomes of the strategic labs as their primary focus was not on indicators like publications and patents.

Thus, there is a need to define the eligibility criteria and the definition of a public R&D lab for the purposes of this exercise.

10.1.2. Revisit weights of the pillars and sub-pillars to better reflect the role of public R&D labs

Three questionnaires were developed for the purpose of this study based on the categorisation of labs and weights were attached to each pillar based on the NITI Aayog report. In the case of hybrid labs, the labs had to fill in multiple questionnaires and ensure their responses were consistent thereby increasing the chances of human error in many cases. It further added to the validation time. Therefore, for the future studies, it is recommended to explore a mechanism wherein a single questionnaire is deployed for all the lab categories without changing the essence of the framework.

Moreover, it was found that the weights of the pillars and sub-pillars may not completely reflect the role of all types of public R&D labs. The expert committee may also consider revisiting the assigned weights of the pillars and sub-pillars at the time of re-evaluation.

10.1.3. Revisit applicability of certain indicators and refining current indicators

It was found that the indicators in the framework may not completely capture the nature and impact of the work done by all kinds of R&D labs. The documentation of the framework did not explicitly provide definitions for each indicator. In this direction, some examples of indicators that may be revisited are:

○ National programmes: While a list of National programmes provided by the working group was used in the current questionnaire, it was observed that many sector specific programmes are missing from the current list. It is recommended that more such national programmes be included to the list based on the research areas being undertaken by the labs.

○ Awards and fellowships: In the current study, only sector agnostic reputable awards and fellowships were included. However, in the interest of making the study more inclusive and based on the feedback from the labs, it is recommended to further include sector-specific reputable awards and fellowships.

○ The expert committee may also consider revisiting the applicability of certain indicators and refining current indicators.

10.1.4. Assistance from domain experts to evaluate qualitative responses

The NITI Aayog report recommended the formation of a committee of retired scientists to assess responses to qualitative questions. This was not possible due to several reasons

for this study. It is recommended to constitute a committee of domain experts to evaluate qualitative responses.

Moreover, as this exercise runs across multiple scientific ministries, consideration may also be given to the formation of sector or ministry specific committees to evaluate subjective responses. The committee's feedback will add more value to the individual labs when they use this data for self-evaluation.

10.2. Institutionalizing the process of data collection and validation

10.2.1. Support of line ministries/departments in data collection

We found that line ministries/departments can play an important role in supporting the data collection process in a more systematic and centralised manner. For example, some data points such as publications and patents can be collated and validated at the ministry/department level.

For the purpose of this exercise, data from databases such as Scopus and Web of Science was requested to standardize the publication data. However, it was found that that many labs did not have access to either database and a lot of time and effort was needed to connect such labs with the other labs that had access to these databases. With this in view, it is recommended that the relevant ministries can furnish individual lab publication data or identify ways to ensure that all the labs have a central access to this information.

In some instances, labs were found to report the same value of their extramural funding received from government sources and their overall budget. Department-level validation of such data points will also help refine this exercise.

10.2.2. Aligning the data reported in the annual reports with the 62 indicators

Some of the data required for this framework is also a part of the annual reports of R&D labs. However, presently, this data is non-standardised and scattered. Aligning the data reported in annual reports with the indicators given in the framework will considerably reduce both the efforts and time. Moreover, the standardised formats presented in the framework may be useful for other administrative purposes within the lab.

10.2.3. Embedding the data templates in portal for effective validation

It has been found that the data validation process was time-consuming despite the standardised data templates and sign-off from Directors. It is suggested that embedded data templates in the portal will reduce the chances of errors and simplify the data collection and validation process. For example, while reporting, human errors were observed in the calculation of scientific staff, women researchers and young researchers. The calculation of such data points can be automated through backend programming.

It is also pertinent to note that the participating ministries/departments have an important role to play in the refinement of the framework going forward. Every effort would need to be made to familiarise the participating ministries/departments about the immense potential of such a framework. Ongoing, iterative and collaborative efforts among all the stakeholders would be necessary to ensure the success of future rounds of this study as well as broaden the scope of such studies across the wider research and innovation ecosystem.

NOTES