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Venni Krishna

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Contact information
Address: Edificio Expo. c/ Inca Garcilaso, 3. E-41092 Seville (Spain)
E-mail: jrc-ipts-secretariat@ec.europa.eu
Tel.: +34 954488318
Fax: +34 954488300

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Abstract
RIO R&I International Country Reports analyse and assess the research and innovation system, including the main challenges, framework conditions, regional R&I systems, and international co-operation.

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Foreword

The report offers an analysis of the R&I system in India for 2015, including relevant policies and funding. The report identifies the main challenges of the Indian research and innovation system and assesses the policy response. It was prepared according to a set of guidelines for collecting and analysing a range of materials, including policy documents, statistics, evaluation reports, websites etc.

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Author's affiliation:

Venni Venkata KRISHNA, Centre for Studies in Science Policy - School of Social Sciences, Jawaharlal Nehru University 402 Dhaulagiri Tower Ghaziabad, Uttar Pradesh, India

Executive summary

India is a country with approximately 1.25 billion people in 29 federal states and seven union territories and is widely recognised as the most populous democracy in the world. India's population is more than double the population of EU's 28 member states of nearly 508 million people. There are several common threads, beyond the feature of democracy, between India and EU. There is the feature of 'unity in diversity' in both India and EU manifested in language, ethnic identities, culture, music and political systems.

India is the fastest growing economy in the world in 2016. India registered an average growth rate of about 7.5% in the last decade compared to negative growth rates for EU in 2012 and 2013. EU began to recover in 2014 exhibiting the growth rate of 1.4%. The overall R&D expenditure doubled since 2007, which stands at US40 billion in 2012 and then to US $ 44 billion in 2014. India's R&D expenditure is 2.7% of the global R&D expenditure compared to USA 33.6%; and Japan and China accounting for about 12.6% each in 2012.[1]

A dominant proportion of India's GERD, around 64.4%, is met by government sources, while 35.6% come from the business enterprises and other sectors. India's R&D intensity increased from 0.81% in 2001-02 to 0.88% in 2011-12. R&D intensity did not witness any major change in the last three years ending 2016. However, the government has committed to increase the investment to 2% of GDP in R&D by the end of the 12th Five Year Plan (2012-17).

India's national innovation system is quite intimately integrated with high level political system. Under the overall administrative and executive control of the Prime Minister's Office (PMO), the structure of the S&T system operates in a coordinated and consultative mode. The top level research policy formulation, planning, coordination and advisory role in S&T from a long term perspective is carried out by three major actors: (i) the National Institution for Transforming India (NITI Aayog), which replaced the earlier Planning Commission; (ii) the Ministry of Science and Technology including the Department of Science and Technology; and (iii) the Principal Scientific Advisor, the Science Advisory Council to the Prime Minister.

The structure and governance of the public R&D system can be characterized as a 'top-down model', particularly with regard to prioritizing research funding. Having laid policy priorities, the research system commands good deal of research and policy autonomy. Whilst the public research science agencies in space, nuclear energy, defence, industrial research in pharma and chemical, among other sectors have emerged as important actors in the NIS. The R&D in business enterprise sector has begun to play an important role in the last five years.

Even though India's proportion of world science output witnessed steady increase from 3.28% in 2010 to 4.40% in 2014, publications counted per thousand population shows that the country is far behind China, EU, USA, among other leading countries.

Two major shifts in the framework of research and innovation can be seen in the last two years after Modi's government coming into power in 2014. The government has given a renewed policy focus to solicit the participation of business enterprises sector through Public-Private Partnerships (PPP) in almost all sectors of economy including the defence and strategic S&T sectors. Secondly, there is a move towards project based and mission mode funding compared to the existing focus on institutional funding. The government during 2015-16 launched a number of National Flagship Programmes, which have created a large demand pattern in S&T, R&D and innovation including human skills at all

[1] See Battelle Report on Global R&D Funding Forecast, https://www.battelle.org/docs/tpp/2014_global_rd_funding_forecast.pdf (accessed 17 may 2016) pages 5 and 7 give data on trends.

levels. Each flagship involves a group of multiple sectors and a heavy coordination through a group of ministries. These programs are:

Make in India

Digital India

Skill India

Green India

Smart Cities and Urban Development

Clean India (Swachh Bharat)

Creating New Infrastructure

All flagship programmes (see section 1.2 for more details) have specific targets and missions to achieve. Together with mission mode approach, the accountability and transparency factor is given importance, as there is an increasing participation of the business sector. Another important programme that was inaugurated by the Prime Minister on 16 January 2016 is the Startup India and Standup India. Those programmes through a series of policies and measures are meant to encourage and boost start-up activity in the country. The government announced INR 10 0000 million fund for 4 years to promote start-ups in India.

The most dynamic aspect of Indian economy in the last decade has been the emergence of hot-spots for global R&D, global innovation and market for information based ICT products and high technology manufactures. India has been a major destination of Foreign Direct Investment in R&D and an attractive knowledge based location for Transnational Corporations such as IBM, Intel, Microsoft, General Electric, among others. In 2015 over 1 070 multinational firms have established R&D centers or laboratories in various cities of India. Between 2000 and 2013, these centers increased at an annual rate of 13.8% giving employment to 244 000 professionals in 2014. These centers mainly operate in ICT, biotechnology, pharmaceuticals, telecommunications and automobiles. During the last decade Bangalore, Pune, Chennai, Calcutta, NCR Delhi and Hyderabad's high technology city are among the major destinations for foreign R&D centers. These cities have emerged as global R&D and innovation hubs or networks with horizontal and vertical integration to globally dispersed innovation and manufacturing value chains.

India has a well-articulated institutional framework to meet multitude of national and global challenges aided by one of the fastest growing economies in the world. There is a good policy mix in place within the broad framework of STI policies of NIS. The major problem has been the interaction and operational linkages between different actors of the NIS, which are rather weak. Similarly, a mix of policy thrust to increase the research intensity in the academic sector with over 700 universities and 35000 colleges has not witnessed any major boost to R&D in higher educational institutions in the last decade. Various schemes and policy measures to commercialize publicly funded research in universities remain at a very low level due to lack of effective mechanisms to bridge linkages between universities and public research institutions on one hand and between universities and industry on the other.

There is over 90% of labour force in the informal sectors of economy and a significant proportion of India's GDP (between 20 to 25%) comes from semi urban, agro-industrial and rural enterprises including more than 2000 industrial clusters. Generating employment and skills to enhance economic levels of nearly 600 million people poses a gigantic challenge for STI policies, particularly finding solutions in inclusive innovation and skills up gradation. The government has responded by launching various flagship programmes such as Skill India and Startup, among others. However, it is too early to assess them. The major challenge of the government however remains in meeting the target of 2% of GDP for GERD in the coming years.

R&I Fact Sheet

Indicator[2]	India (2015)	*EU-28*
Number of inhabitants (Million)	1,282	*506.6*
GDP MEUR*	US$2.4 Trillion (PPP 8.8 Trillion US$)	*13 068 600**
GDP per head (index, EU28 = 100 EUR per capita)	100 US$1820 (PPP US$6664)	*100* *26 600*
Real GDP growth rate (%)	7.5%	*0.1%*
Agriculture weight in the economy (%)	17% (GVA[3]) 49% (employment)	*1.7%* *5.1%*
Industry & construction weight in the economy (%)	18/% *manufacturing* (GVA) 20% *manufacturing* (employment)	*24.8% (15.1%)* *22.4% (14.3%)*
Services weight in the economy (%)	65%(GVA) 31% (employment)	*73.6%* *72.4%*
Employment rate, aged 20-64 (% of population)	70.3% (51% self-employed)	*68.4%*
Unemployment rate (% of the active population)	5%	*10.9%*
Early leavers from education and training (% of population aged 18-24)	10%	*11.9%*
	Target 2020: 15%	*Target 2020:10%*
Tertiary educational attainment (% of population aged 30-34)	23.6 (Gross Enrolment Ratio)	*37.1%*
	Target 2020: 30%	*Target 2020: 40%*
Total government expenditure (MEUR % of GDP)	INR 3365 billion	*6 412 328*
		49.1%
General government gross debt (% of GDP)	66%	*87.1%*
General government deficit (% of GDP)	4.3%	*-3.3%*
Human Development Index (HDI), *Source*: UNDP	0.609 *(xxth)*	*EU max (NL): 0.915* *EU min (BG): 0.777*
PISA Ranking, *Source*: OECD, 2012 (reading; mathematics; science)	na	--

The RIO international report on India provides an overall insight into India's national science, technology and innovation system. The structure of the report is divided into six main chapters excluding annexes. The first section of the report provides an overview of the R&I system. It main covers national R&I strategy, main R&D programmes, R&I policies and system of governance, the main research performers, the quality of science and the main policy changes that have come about in the last five years.

The second section deals with public and private funding of the R&I system and expenditure. It covers funding flows, the main research funders and different types of funding mechanisms institutionalised in the R&I system.

The third section of the report provides the policy environment for business, the initiatives taken for start-ups and knowledge transfer.

The fourth section deals with smart specialisation approaches in the governance and funding of the R&I system. It also covers the issue of regional linkages.

The fifth section of the report deals with internationalization of R&I system. It covers the issue of globalization of innovation and R&D system, international cooperation in S&T and a very comprehensive coverage of India's cooperation with EU and other leading countries such as USA. A special focus is also laid on the activities of JRC and its links with India. Some excellent organizations involved in Indian S&T policies, innovation and networking activities across a range of S&T fields is given. These organizations and institutions could be good sources for JRC cooperation in undertaking various studies.

[2] Eurostat data 2013 unless otherwise indicated
[3] Gross Value Added (GVA) at basic prices equals GDP minus taxes on products plus subsidies on products.

The concluding remarks are given in the sixth section of the report. Here the focus is laid on structural challenges of the R&I system, structural challenges and SWOT analysis as a way of main lessons and implications for the EU – India relations.

The report was prepared according to a set of guidelines for collecting and analysing a range of materials, including policy documents, statistics, evaluation reports, websites, etc. The quantitative and qualitative data is comparable across other country reports whenever possible.

1. Overview of the R&I system

1.1 Introduction

The report was prepared according to a set of guidelines for collecting and analysing a range of materials, including policy documents, statistics, evaluation reports, websites, etc. The quantitative and qualitative data is comparable across other country reports whenever possible.

India is a country with approximately 1.28 billion people in 29 federal states and seven union territories and is widely recognised as the most populous democracy in the world. India's population is more than the double of EU's 28 member states population of nearly 508 million people. There are several common threads, beyond the feature of democracy, between India and EU. There is the feature of 'unity in diversity' in both India and EU manifested in language, ethnic identities, culture, music and political systems.

After witnessing economic growth rate at an average of 8.3% per year for the period from 2004/05 to 2011/12 (Economic Survey 2013-14, p3), India's growth rate decelerated during 2012/13 to 2014/15 to around 6.4% per year according to the Economic Survey released by the government in 2014-15. This recent survey forecasts a growth rate of 8% in 2016-17. The World Bank and IMF give somewhat similar accelerating growth rate forecasts. India's is the fourth largest economy in the world on PPP terms and India's per capita income is US $3176 (PPP). Indian economy has exhibited a stable economic situation against world recessionary trends and emerged as one of the fastest growing economies in the world. India registered GDP growth rates of 5.6%, 6.6% and 7.2% for 2012, 2013 and 2014 respectively compared to negative growth rates for EU for 2012 and 2013. EU began to recover in 2014 exhibiting the growth rate of 1.4%.

India exhibited considerable fiscal prudence in the last three years registering continuous reduction in the gross fiscal deficit as per of GDP as shown in the Table 1. From 4.9% of fiscal deficit of GDP in 2012, the government budget in 2016-2017 projected a figure of 3.5% of GDP. According Economic Survey in 2015-16, employment growth in the organized sector, public and private, increased by 2% in 2012 compared to 2011. The private sector registered a better employment growth rate of 4.5% for 2012 but it in fact came down compared to 2011, which was 5.6%. As shown in Table 1, the national unemployment registered somewhat stable figure of 3.6% for 2012-2014.

In 2013-2014, the sector share of total employment reveals that 48.9% in agriculture and allied sector; 24.3% in industry and 26.9% in the services sector. A remarkable feature of employment of labour force in India is the predominance of informal sector, which accounts for more than 90% of total labour force. Another feature is the component of more than 50% of informal workers in the formal sector. Among the sectors that have registered better employment growth prospects during 2014-2015 are IT/BPO, textiles, metals and automobiles. These sectors registered growth of 178, 135, 28 and 7 persons per 1000 respectively. Whereas handloom, leather, transport and gems and jewellery registered negative figures of -17, -17, -12, and -6 respectively for the same period.

Nearly half of India's labour force is involved in agriculture and allied sectors but contribute merely 14% of national Gross Domestic Product (GDP) output in 2014. About 20% of labour force in industry and contribute over 26% of national GDP. The most robust is the services sector which account for about 31% of labour force but contribute nearly 60% of national GDP in 2014. During the last three years the agriculture sector did not exhibit any robust growth and in fact has come down from 4.2% in 2013 to 1.1% in 2015. Whilst industry has been growing on an average about 6% per annum in these years, services sector registered growth of average of 9%.

According to the Economic Survey, 2015-16, Indian services sector ranked ninth in terms of overall world GDP and tenth in terms of world gross value added in 2014. Services has been the most robust of sectors attracting more than half of total FDI flown into the country of US$30.9 billion. FDI growth in services registered 70% and industry FDI growth registered around 31% in 2014. The government launched 'Make in India' flagship programme and policy thrust in 2014. With this, there has been an increase of 40% in FDI in 2015. As the Economic Survey, 2016 states, 'with the objective of making India a global hub of manufacturing, design and innovation, the Make in India initiative, which is based on four pillars --new processes, new infrastructure, new sectors and new mind-set—has been taken by the government. The initiative is set to boost entrepreneurship, not only in manufacturing but in relevant infrastructure and service sectors as well. An interactive portal http://makeinindia.com for dissemination of information and interaction with investors has been created with the objective of generating awareness about the investment opportunities and prospects of the country, to promote India as a preferred investment destination in markets overseas and to increase Indian share of global FDI. In addition, information on 25 thrust sectors, along with details of the FDI Policy, National Manufacturing Policy, Intellectual Property Rights and the proposed National Industrial Corridors including the Delhi Mumbai Industrial Corridor (DMIC), are available on the portal'.[4]

The services export has been the most dynamic feature of India's trade among all the three sectors. WTO data shows that India's services export grew from US $ 16.8 billion in 2001 to US $ 155.6 billion which accounts for 7.5% of national GDP. Whereas in the services sector, gross value added has been growing at a rate of above 11% per year in the last three years, gross value added for manufacturing has been rather stagnant for the same period.

A dominant proportion of GERD, around 64.4%, is met by government sources, while 30% come from the business enterprise sector. India's R&D intensity increased from 0.81% in the years 2001-02 to 0.88% in 2011-12. By means of comparison, the EU's average is above 2.2%; the USA spent around 2.76%; China spent 1.8% and South Korea 4% in 2011-12.One of the major problems for an economy of size like India is the relatively low investment in GERD compared to other leading and BRICS countries. Even though the business enterprise sector in the last decade increased its share from 18% to nearly 35.6% (including 2% from private non-profit) of GERD in 2011-2012, both the public and private investments in R&D have not kept pace with the growth of the economy, which nearly doubled (in terms of GDP) during the last 12 yrs. It may however be noted that actual GERD increased more than fourfold between 2002 and 2012. The total figures of R&D expenditure of India which was Rs 17,038.15 crores (US $3.48 billion) in 2002, increased to a figure of Rs 72620.44 crores (US $13.1 billion) in 2012 showing clearly more than fourfold increase.

In so far as the figures of R&D intensity are concerned, they did not witness any major change in the last three years ending 2016. However, the government has committed to increase the investment from the current less than 1% to 2% of GDP in R&D by the end of the 12th Five Year Plan (2012-17). It is expected that the country will reach the target of 2.2% of GDP for R&D by 2020. Even though India did not confront any severe economic crisis, the government is yet to keep up its commitment to increase R&D/GDP to 2%. The movement has been relatively slow.

The new government led by Modi has enunciated a half dozen flagship programmes and policies to promote them under PPP model. This has already generated considerable demand pattern for R&D and innovation inputs. There are several sectors of economy such as defence, infrastructure and railways which are now open for private and

[4] http://indiabudget.nic.in/es2015-16/echapvol2-06.pdf, See also Economic Survey 2015-2016, The Finance Ministry, Government of India.

international participation. The government is making effort to ease doing business in the country. The last two years witnessed unprecedent robust economic reforms and measures to liberalize trade and investment.

Table 1 Main R&I indicators 2012-2014

Indicator	2012	2013	2014	EU average 2014
GDP per capita	1481 US$	1487 US$	1631 US$	27,300 EUR
GDP growth rate	5.6%	6.6%	7.2%	1.3%
Budget deficit as % of GDP	4.9%	4.5%	4.0%	86.8%
Government debt as % of GDP	67.5%	65.8%	66.1%	-2.9%
Unemployment rate as percentage of the labour force	3.6%	3.6%	3.6%	10.2%
GERD in €m	8698	No data	No data	268,672
GERD as % of the GDP	0.88	No data	No data	1.936
GERD (EUR per capita)	No data	No data	No data	No data
Employment in high- and medium-high-technology manufacturing sectors as share of total employment	N/A	N/A	N/A	5.6(2013)
Employment in knowledge-intensive service sectors as share of total employment	N/A	N/A	N/A	39.2%
Turnover from innovation as % of total turnover	N/A	N/A	N/A	11.9% (2012)
Value added of manufacturing as share of total value added	N/A	N/A	N/A	No data
Value added of high tech manufacturing as share of total value added	N/A	N/A	N/A	No data

1.2 National R&I strategy

There is a clear national research and innovation strategy articulated by the government. In 2010 the President of India declared 2010-2020 as the 'Decade of Innovation'. The government followed up with the announcement of Science, Technology and Innovation

Policy, 2013 (STIP 2013). This policy meant a step forward in attempting to forge the links between the science, technology and innovation policy framework. The main goals of this policy are:

- STIP 2013 aims to enhance the role of the private sector in the national science, technology and innovation system in a public-private partnerships (PPP) mode, towards attaining the target of 2% of GDP in research and development (R&D).
- Positioning India among the top five global scientific powers by 2020.
- STIP 2013 seeks to integrate agriculture R&D policy with the national R&D system.
- STIP 2013 will promote mechanisms such as a 'Risky Idea Fund' and a programme called 'Small Idea Small Money' to capitalize on the existing proposals of the National Innovation Council.
- Increasing R&D personnel by two-thirds, within five years; and publications from the current 3.5% of global share to around 7% by 2020.

Modi's government identified in 2014 a number of National Flagship Programmes or Missions, which entail S&T, R&D and technological inputs and resources including financial and human skills. Each flagship programme involves a group of multiple sectors and a heavy coordination through a group of ministries. This is a major change in the social and economic policies in the last three years.

These programs are:

- Make in India
- Digital India
- Skill India
- Green India
- Smart Cities and Urban Development
- Clean India (Swachh Bharat)
- Creating New Infrastructure

Note: More details on these flagship programmes are given at the end of this section.

The Prime Minister Narendra Modi has been very pro-active through his Prime Minister's Office (PMO) and NITI Ayog which has replaced earlier the Planning Commission. Beyond the ministry of science and technology, the government has empowered most other ministries such as railways, power, telecommunications, transport, ICT, environment, renewable energy,… to implement respective flagship programmes within the overall direction of PMO.

There are some programmes for which implementation and targets are announced by the government. The Clean India programme set a target date of 2019 to achieve its mission of clean India. The 2016-17 budgets underlined the policy goal of doubling agricultural income in five years. The government already issued Unique Identification Cards (Aadhar Card) to 900 million people. These cards are based on digital biometric information, equivalent to National Social Security Card in several countries. The target is to cover the whole of India's 1.25 billion people by end of 2019.

A major thrust of Digital India, as indicated by the Prime Minister, is to aggressively promote manufacturing of electronics in India. There is an ambitious plan to manufacture all electronic needs of the country indigenously by 2020 saving around 400bn US$ in foreign exchange. Even though the mobile penetration is quite substantial with 950 mobile users now in India, internet penetration is relatively low both in a mobile and a surface mode. There are currently about 213 million mobile internet users. The broadband services user-base in India is expected to grow to 250 million connections by 2017. The sector is expected to grow at more than 15 to 20% per annum.

There is an ongoing activity under the National Knowledge Network (NKN) – a broadband network to connect all educational and research institutions in the country.

This is extended to international gateways. The final part of this connectivity focus under the present government is the goal to ensure last mile connectivity and internet access to the rural population through a National Optical Fibre Network (NOFN). The initiative will begin by connecting 250,000 villages.

Under Smart Cities and Urban development programme there are two flagship programmes. The first is the pet project of the Prime Minister, aiming at building 100 smart cities with a budget allocation of INR 480,000 million for five years. The second is the new urban development scheme called Atal Mission for Rejuvenation of Urban Transformation (AMRUT) with an enhanced budget allocation of INR 500,000 million. The latter is however the continuation of the previous government's Urban Renewal Mission programme

All the flagship programmes and various targets that have been announced have very clear implications for research and innovation policies. Most programmes have clear linkages with industrial policies. For instance, the programme on skill India is linked to 2016 policies on 'start up – stand up India' policy initiative. Similarly infrastructure projects and programmes have influenced the recent government policies to build ports and air ports.

Various flagship programmes and policy expectations to bring about double digit economic growth and modernization needs a very organized and coordinated STI strategy with corresponding institutional mechanisms. Earlier, such coordination was either entrusted with the Planning Commission or some other advisory body to the Prime Minister. With the dismantling of Planning Commission, the NITI Ayog and PMO in the current government is set to drive the coordination mechanism between various actors of the innovation system. It may be mentioned that such a strategy for coordination and implementation is slowly emerging and yet to become operational.

When we compare the Indian R&D and innovation strategies with those of EU, it is rather difficult to say that India will be able to match the EU 2020 strategy and achieve the 3% target of research intensity. India's current R&D intensity figure of less than 1% is relatively stagnant for the last decade. However the government is committed to raise this figure to 2% by 2020.

Details of Flagship Programmes

Make in India

The Prime Minister announced this programme on the occasion of India's Independence Day on 15 August 2014. He said 'come, make in India. Come and manufacture in India. Go and sell in any country of the world, but manufacture here. We have skill, talent, discipline and the desire to do something. We want to give the world an opportunity that come make in India'. This national programme of the Government of India is structured in a way to promote investment, innovation, enhance skill development, protect intellectual property and build manufacturing in the country. The program is steered by the Department of Industrial Policy and Promotion (DIPP), Ministry of Commerce and Industry. It seeks to make use of India's existing talent base and at the same time envisages creating additional employment opportunities in the secondary and tertiary sector. 25 sectors are identified where the program will be initiated. The government created an investor facilitation cell (www.makeinindia.com). Secondly, the government opened up a vast range of sectors for foreign direct investment (FDI). In some sectors such as railways, the government allows 100% FDI and in other sectors such as defence it allows 55% of FDI. There are some early results of the campaign of Make in India:

- The European controlled AIRBUS consortium has entered into collaboration with Mahindra Group, which manufactures jeeps, SUVs and cars in India. Both groups formed a joint venture to produce helicopters in India and jointly bid for defence projects. Guillaume Faury, Airbus Helicopters CEO observes that 'the joint venture will be dedicated to supplying the Indian Armed Forces with Made-in-

India, state of the art helicopters of high reliability, quality and safety standards based on combat-proven platforms'.

- German automotive firm Mercedes Benz has decided to double its assembly capacity in India;
- Ford USA decided to export cars from India to USA;
- Hitachi has decided to set up auto component production in Chennai's Auto hub;
- Huawei, a Chinese multinational, opened a new R&D campus in Bangalore; and
- iPhone producer Foxconn is planning to set up the first Apple Plant in India as LG, South Korea had already begun to manufacture smartphones in India.

Digital India

The new flagship programme 'Digital India' aims at the continuation of India's relative success in the ICT software, e-governance and telecommunications sectors in the last decade. India is currently exporting about 100bn US$ worth of software and related services in engineering, health etc. India stands next to China in mobile diffusion with 950 million mobile phones being used by the population. The major thrust of this new programme is to leapfrog to a new paradigm on the basis of the solid platform already created to bridge the digital divide. On July 2nd 2015, the Prime Minister formally inaugurated the Digital India programme. He set out a very ambitious goal to deliver governance through mobile phones and to expand the internet connectivity throughout the country. There is also the goal to deliver services relating to health, education and social welfare through 'information highways'. The government already issued Unique Identification Cards (Aadhaar Card) to 800 million people. These cards are based on digital biometric information, equivalent to National Social Security Card in several countries. The work is in progress to cover India's entire population. Even though the mobile penetration is quite substantial, internet penetration is relatively low, both in a mobile and a surface mode. There are currently about 213 million mobile internet users. The broadband services user-base in India is expected to grow to 250 million connections by 2017. The sector is expected to grow at more than 15 to 20% per annum.

There is an ongoing activity under the National Knowledge Network (NKN) – a broadband network to connect all educational and research institutions in the country. National Optical Fibre Network (NOFN) initiative will begin by connecting 250,000 villages.

The second important feature of Digital India is the creation of platforms for all types of e-services (passports, driving license, tax bills, health, education etc.) through the Aadhar Card platform and other expansions of mobile broadband services. GIS services will be made use of to track mobility, progress of work, to map physical assets etc.

The third important feature of Digital India is applications and programmes across a range of sectors from education, health and various other socio-economic and commercial services. Closely linked to this is making available government information of all types from development to decision-making on an Open Government Platform (OGPL).

The fourth important feature is the creation of data centres and a framework for cyber-security to offset attacks. Four large national data centres have been set up in Delhi, Bhubhaneshwar, Hyderabad and Pune. Big Data analysis features are closely linked to these centres, but are administered separately.

A major thrust of Digital India, as indicated by the Prime Minister, is to aggressively promote manufacturing electronics in India. There is an ambitious plan to manufacture all electronic needs of the country indigenously by 2020 saving around 400bn US$ in foreign exchange. Leading Indian industrialists and some foreign industrialists who gathered at the formal launch of Digital India committed 4.5 Trillion INR in the coming five years. India's 12th Plan already envisaged knowledge networks and expanding the internet and digital services, but the new government has made this an important flagship programme of the country with clear-cut goals and targets to achieve. For instance, in the 2015-16 budget, the Finance Minister already allocated budget for 750 000 km networking through optical fibre connecting 250 000 villages.

Skill India

As is well known by now, India is a young country with great potential to reap the benefits of the demographic dividend. As India's Finance Minister pointed out, in 2015, 54% of India's 1.25 billion people are under the age of 25 years. The demographic profile of the country is such that in the coming 25 years a predominant section of India's population is likely to be in the age group of 35-60. Thus, education, skills, training and entrepreneurship are likely to be very crucial towards the target of 8-10% GDP growth per year in the coming decade. From this perspective, the new flagship programme Skill India was launched by creating a new Ministry of Skill Development and Entrepreneurship (MSDE) out of the earlier Labour Ministry, which had a wing dealing with Skill development. Soon after forming MSDE, the government lost no time in revising the 2009 National Policy on Skill Development (NPSD 2009), issuing the National Policy on Skill Development and Entrepreneurship, 2015 (NPSDE 2015).

According to the new NPSDE 2015 policy, an estimated 25.97 million people are expected to enter the workforce every year. By 2022, this figure is estimated to be total/sum of 181.79 million people. As the policy further points out, 119.5 million people need to be trained by 2022, which translates into 17.07 million people per year from 2015. The 2015 budget launched a scheme called Deen Dayal Upadhyaya Gramin Kaushal Yojna for training, education and entrepreneurship. The skill development ministry is entering into partnerships and collaborations with several EU countries such as Germany, France and other countries such as Japan, South Korea and Australia in drawing on their experiences and for developing viable collaborations for India's skill mission.

Green India

Green India has a major thrust focusing on renewable energy technologies and innovation. As the Finance Minister recently noted, India's 'Carbon Tax' on petroleum products compares favourably with international norms. The 2015 budget made special allocation to launch a new scheme called 'Faster Adoption of Manufacturing of Electric Vehicles' (FAME). This will complement the E-Car being produced by Mahindra group under the brand name REVA. Through the Ministry of New and Renewable Energy, the Green India programme has announced a new target of renewable energy: 175,000 MW of capacity in 2022 comprising 100,000 MW solar; 60,000 MW of wind; 10,000 MW of biomass and 5,000 MW of small hydro projects. About 700,000 jobs are expected to be created through achieving the new targets by 2022. The previous government earlier laid a very solid foundation and framework for a Sectorial System of Innovation in the Solar Sector through the Jawaharlal Nehru Solar Energy Mission I & II programmes. The current initiative is to further leapfrog on this platform.

Smart Cities and Urban Development

There are two flagship programmes under this heading. The first is the pet project of the Prime Minister, aiming at building 100 smart cities with a budget allocation of INR 480,000 million for five years. The second is the new urban development scheme called Atal Mission for Rejuvenation of Urban Transformation (AMRUT) with an enhanced budget allocation of INR 500,000 million. The latter is however the continuation of the previous government's Urban Renewal Mission programme.

There are three basic features of the definition of smart city, namely: a) a city equipped with basic infrastructure to give a decent quality of life, a clean and sustainable environment through application of some smart solutions; b) basic infrastructure such as water, electricity supply, solid waste management, urban mobility and public transport, e-governance, citizen participation and safety and security of citizens; and c)a city which will have smart solutions to services, public grievance, 100% treatment of waste and several processes which go into managing modern cities. The government already allocated quota of smart cities to various State governments. Uttar Pradesh will build 13; Tamil Nadu 12; and Maharashtra 10. While Japan is assisting in converting Banaras into a smart city, France has evinced interest in about 3-4 cities. These initiatives have come about during Prime Minister's visits to these countries in this year.

Clean India

There are two Major thrust programmes for Clean India. The first is the cleaning of Ganga River, which flows from the foothills of the Himalayas and travels 2 000 km passing several states, covering 41 tributaries and finally ending up at the Bay of Bengal near Kolkata. A new flagship programme called Namami Gange Programme (NGP) with a budget allocation of INR 200,000 million for five years has come into operation. NGP is a multi-sectorial, multi-dimensional and multi-stakeholder Ganga Rejuvenation programme. Hence, the key Ministries including (a) Water Resources and Rural Development, (b) Environment, Forests & Climate Change, (c) Shipping, (d) Tourism, (e) Urban Development, (f) Drinking Water and Sanitation and Rural Development have been working together since June 2014 to arrive at an action plan. There is a Group of Secretaries tasked to develop a draft action plan. About 17 Indian Institutes of Technology and other R&D and S&T institutions are linked with the NGP. The Clean Ganga Project has assumed special significance, as Banaras or Varanasi is the Prime Minister's constituency.

The second flagship project of Clean India is the Swachh Bharat Abhiyan (Clean India Campaign), which is mainly directed at cleaning neighbourhoods and eradicating open defecation by providing toilets. Launched in 2014-15, it also aims at building toilets at schools and other training institutions located in rural areas. The massive programme involves various innovations in social and technical fields. The government has set a target to eliminate open defecation by the 150th birth anniversary of Mahatma Gandhi in 2019. The Clean India Programme is collaborating with the Melinda and Bill Gates Foundation and EU countries such as Netherlands.

Creating New Infrastructure

A big push for infrastructure is given in the 2015 budget, which allocated INR 700,000 million to infrastructure covering, roads, railways, ports, and a range of sectors. A notable point of this programme is the rejuvenation of public-private partnerships on a new footing. The private sector will play a major role in building India's future infrastructure in the coming five years. The Reserve Bank of India (RBI) has allowed 100 per cent foreign direct investment (FDI) under automatic route in the construction development sector. The Indian port sector is likely to witness tremendous strides, as by the end of 2017 port traffic will amount to 943.06 MT for India's major ports and 815.20 MT for its minor ports. This amounts to a 40% increase compared to previous years. Along with that, the Indian aviation market is expected to become the third largest across the globe by 2020, according to industry estimates. The sector is projected to handle 336 million domestic and 85 million international passengers with projected investments to the tune of 120bnUS$.

The government decided to promote five industrial corridors in India stretching the length and breadth of the country. These are: Delhi-Mumbai Industrial Corridor (DMIC); Bengaluru- Mumbai Economic Corridor (BMEC); Chennai-Bangalore Industrial Corridor (CBIC); Visakhapatnam-Chennai Industrial Corridor (VCIC) and Amritsar-Kolkata Industrial Corridor (AKIC). Among these, DMIC has already come into operation. This is a State-Sponsored Industrial Development Project with a budget of100 billion US$. The project aims at developing Industrial zones spanning across six states in India, which will create economic, and employment potential together with developing industries along the corridor. DMIC received support from Japan, which has entered into an agreement to set up a project development fund with equal co-investment. The initial size of the Fund will be INR 10 billion (158.7 million US$). The Dedicated Freight Corridor is expected to be completed by 2017.

It would be the biggest infrastructure project India has ever attempted in its history. The project will see major expansion of infrastructure and industry – including smart cities, industrial clusters along with rail, road, port, and air connectivity – in the states along the route of the Corridor. Many smart cities would be developed alongside.

India and the USA have signed a memorandum of understanding (MoU) in order to establish an Infrastructure Collaboration Platform. The document showcases the relationship between both Governments, which intend to facilitate US industry participation in Indian infrastructure projects to improve the bilateral commercial relationship and benefit both the Participants' economies. The MoU's scope envisages efforts in the areas of Urban Development, Commerce and Industry, Railways, Road Transport and Highways, Micro Small and Medium Enterprises, Power, New & Renewable Energy, Information and Broadcasting, Communications & Information Technology, Water Resources, River Development and Ganga Rejuvenation'.

Indian Railways and French National Railways (SNCF) will co-finance a feasibility study by SNCF for a semi-high speed project on upgrading the Delhi-Chandigarh line to 200kph and for the re-development of the Ambala and Ludhiana railway stations in Punjab. The Indian High Speed Rail Corporation and the Rail Vikas Nigam Limited under the Ministry of Railways will sign an agreement with the China Railway Siyuan Survey and Design Group for developing high-speed trains between Delhi and Chennai at 300kph stretching 1754kms.

All projects and sub-programmes commissioned under any of the above flagship initiatives are to be awarded on global competitive basis. Both Indian public and private firms and international enterprises and institutions are eligible for taking up projects. As most of the projects under flagship programmes are newly launched, it is too early to comment on the process of evaluation.

1.3 R&I Policy initiatives, monitoring, evaluations, consultations, foresight exercises

Research and innovation policies, schemes and instruments up to 2012-13, introduced by the previous government led by Dr Manmohan Singh, can be found in the India profiles at the two EU supported STI policy web directories, namely ERAWATCH[5] and InnoPolicy Trend Analysis. References on STI policies, schemes and instruments introduced by the new Modi government after 2014 are list hereunder.

i) **National Policy on Skill Development and Entrepreneurship 2015:** On July 1st, 2015 the union cabinet of the government of India approved the National Policy on Skill Development and Entrepreneurship 2015.

ii) **Self-Employment and Talent Utilisation (SETU)[6]:** Connected to the larger governmental commitment of providing skills and entrepreneurship the current government has announced to set-up a program called Self Employment and Talent Utilisation (SETU).

iii) **Atal Innovation Mission (AIM)[7]**: Atal Innovation Mission will be an Innovation Promotion Platform involving academics, entrepreneurs, and researchers drawing upon national and international experiences to foster a culture of innovation, R&D in India.

iv) **National Biotechnology Development Strategy -2014**:[8]The Department of Biotechnology in 2007 had formulated the National Biotechnology Development Strategy which was termed as the 'Biotech Strategy-I'. Reviewing the existing biotechnology strategy the Department of

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5 http://erawatch.jrc.ec.europa.eu/erawatch/opencms/information/country_pages/in/country Report by V.V.Krishna, 2013
6 http://niti.gov.in/content/setu.php
7 (http://niti.gov.in/content/aim.php)
8 (http://www.dbtindia.nic.in/national-policy-guidelines-regulations/policies)

Biotechnology in 2014 formulated and brought another strategy document called the 'National Biotechnology Development Strategy – 2014 which was termed as 'Biotech Strategy-II'.[9]

v) **Consolidated Foreign Direct Investment Policy, 2015[10]**: The consolidated Foreign Direct Investment (FDI) Policy, 2015 is a policy document related to foreign investment in the country. This policy plan encourages foreign investment in the country for creating domestic capital, technology & skills development and for the overall economic growth of the country.

vi) **National IPR Policy (Draft)[11]:** The latest 'National Intellectual Property Rights (IPR) Policy draft which came on 19th December, 2014 is an attempt to update, strengthen and to make the current IPR mechanisms more inclusive. This is very much related to both International and National obligations which India has towards the global world and its own people.

There are various schemes to stimulate research and innovation in India. These are operated by DST and DSIR under the Ministry of Science and Technology. The Table below lists some of the important ones, which are in force as of 2016.

Table 2: Some Important Research Schemes

Name of the scheme	Operated by	Main remarks
Small Business Innovation Research Initiative	DBT	To provide support for early stage, pre-proof-of-concept research in biotechnology by industry
Technology Systems Development Programmes (TSDP)	DST	To convert proof of concept/idea/initial process to commercialization across industry sectors
Technology Refinement and Marketing Programme (TREMAP)	TIFAC, DST	For pushing the innovative technologies, up the commercialization cycle, towards market utilization.
Promoting Innovations in Individuals, Start-ups and MSMEs (PRISM)	DSIR	To support individual innovators
Technology Development and Utilization Programme for Women (TDUPW)	DSIR	To encourage women for technology development
Patent Acquisition and Collaborative Research and Technology Development (PACE)	DSIR	To encourage Indian industries to acquire patent from India or abroad.
Centres of Excellence and Innovation in Biotechnology (CEIB)	DBT	The scheme is for promotion of excellence in interdisciplinary science and innovation in specific areas of biotechnology.

9 http://timesofindia.indiatimes.com/india/Draft-biotechnology-strategy-documents-highlights-importance-of-GM-crops/articleshow/31357500.cms
10 (http://dipp.nic.in/English/policies/FDI_Circular_2015.pdf)
11 http://dipp.nic.in/English/Schemes/Intellectual_Property_Rights/IPR_Policy_24December2014.pdf

Biotechnology Parks and Incubators	DBT	To facilitate product advancement and innovation through the development of biotechnology industrial cluster and to produce biotechnologists and entrepreneurs
Research and Innovation Schemes Introduced since 2014-2015		
Stimulating Investments in Biotechnology and Textiles through Clusters	DBT	Development of biotechnology clusters in Faridabad and Bangalore; and 6 mega clusters in Textiles at Barelly, Lunctnow, Surat, Kutch, Bhagalpur, Mysore and one in Tamil Nadu
National Biotechnology Development Strategy	DBT	To regulate biotechnology and encourage excellence
National Policy on Skill Development and Entrepreneurship 2015	Ministry of skill Development	To encourage start-ups and young entrepreneurs
Deendayal Upadhyaya Gramin Kaushal Yojna (2015)	Ministry of Skill Development	For providing training in skills for rural youth
Atal Innovation Mission	National Institute for Transformation of India (NITI Ayog)	The mission will be an Innovation Promotion Platform involving academics, entrepreneurs and researchers and drawing upon national and international experiences to foster a culture of innovation
Self-Employment Talent Utilization (SETU) Scheme	NITI Ayog	To encourage self-employment and start ups
Consolidated Foreign Direct Investment Policy	Department of Industry	Encourages foreign investment in the country for creating domestic capital, technology & skills development.

Source: Generated from Various Government of India Documents and Websites

As these policies, schemes and programmes stand and initiated for research and innovation, seem to be operating separately. As noted earlier, linkages and mechanisms of coordination between research, innovation and educational aspects and actors is a weak link in the national innovation system. There is a strong move by the government to strengthen this link by entrusting greater responsibility on the part of various concerned ministries. For instance, the ministries of railways and transport in a changed scenario have become pro-active on technological and innovation related issues and concerns.

The policies enunciated by the new government after 2014 have recurrently underlined the importance of research infrastructures and innovation eco-system. However, the policy discourse and policy thrust of the government on research and innovation has not yet resulted in the increase of R&D intensity. This in a large measure has prevented the move towards taking India's research infrastructure to a higher level. For instance, the research intensity in the university and higher education sector is staggeringly low compared to EU, South Korea, Japan and China. The yearly increase of 10 to 15% of GERD in some sectors and science agencies (see section 2 on funding) is not sufficient to achieve the stated policy goals of strengthening knowledge base and basic research in the public research system as a whole.

Monitoring and Evaluation

Given the dominant nature of public research landscape where much of the research is of public good nature, the mechanisms of evaluation in the Indian case are organized at different levels. The Parliament has instituted several committees such as Public Accounts and the Committee on Public Undertakings and Departmentally Related Standing Committees (DRSCs). The Committee on Estimates, the Committee on Public Accounts, the Committee on Public Undertakings and DRSCs play an important role in evaluation of various defence, science and technology and other related departments dealing with research.

There is also an autonomous Comptroller and Auditor General of India which periodically assesses and evaluates expenditure on R&D and Science and Technology activities. The Prime Minister's Office and various other ministries constitute evaluation committees from time to time. For instance, the Department of Science and Technology, Department of Biotechnology and Department of Scientific and Industrial Research by and large follow the universal peer evaluation systems in project based funding. There are also special committees constituted for various projects dealing with Nano mission, Water mission, telecommunications mission etc.

Evaluation and Assessment for Higher Education and Research: The National Assessment and Accreditation Council (NAAC) is established by University Grants Commission (UGC) to assess and accredit institution of higher learning in the country. The Universities are evaluated on the basis of universal peer evaluation systems. The mission statements of the NAAC aim at translating the NAAC's vision into reality, defining the following key tasks of the organization:

- to arrange for periodic assessment and accreditation of institutions of higher education or units thereof, or specific academic programme or projects;
- to stimulate the academic environment for promotion of quality of teaching-learning and research in higher education institutions;
- to encourage self-evaluation, accountability, autonomy and innovations in higher education;
- to undertake quality-related research studies, consultancy and training programme; and
- to collaborate with other stakeholders of higher education for quality evaluation, promotion and sustenance.

Much of the evaluation of funding basic research projects at DST is undertaken by its Science and Engineering Research Board. At a national level, much of the evaluation of research is mainly carried out by the specialised Parliamentary bodies such as Public Accounts Committee. India is benchmarking monitoring and evaluation measures from other countries to make Indian STI system more accountable and productive. For instance, the NACC is looking into various measures to learn from world class universities in other leading countries. The ministry of science and technology is seriously looking into monitoring and evaluation system of South Korea on tax incentives in R&D given to private sector and small business innovation measures adopted in the case of USA. On the whole, the evaluation and monitoring system in research and innovation is just beginning to emerge in the Indian context. The DST in 2014 begun to issue reports on innovation surveys covering parts of Indian industry and particularly SMEs sector. DST is planning a nationwide innovation survey in 2016.[12]

In the case of foresight and forecasting, the DST has pioneered in these exercises in the mid-1990s through its specialised unit called Technology Information, Forecasting and Assessment Council (TIFAC). It produced 17 reports involving 5000 experts across a

[12] http://nationalinnovationsurvey.nstmis-dst.org/

range of science, technology and industry related sectors. The outcome was the Technology Vision 2020 documents.[13] Over the years and particularly in the last two years, TIFAC has embarked on a large foresight exercise called Technology Vision 2035 covering dozen thematic areas.[14] The major problem with TIFAC seems to be low priority given to social sciences taking into account the notions of risk, hazards and other social assessment of technology themes including the whole theme of environmental risk assessment.

The National Science and Technology Management Information System (NSTMIS), of DST is established with the task of generating the information base on a recurrent basis on resources devoted to scientific and technological activities for policy planning in the country.[15] It brings out output and various other indicators through R&D statistics. It recently launched a National S&T Survey in 2015-16 towards producing various indicators. The quantitative and statistical information produced by NSTMIS has been quite useful and decision making in S&T and R&D in the NIS. The major problem has been the backlog in the production of R&D statistics.

1.4 Structure of the national research and innovation system and its governance

1.4.1 Main features of the R&I system

Overview of the main R&D programmes

India's main R&D programmes in 2015-16 spans across a range of science and technology fields in different public research institutions. The most important ones which are in operation in 2015-2016 are as follows:

Nuclear: The government has given very high importance to energy sector. Energy generation through nuclear energy is among the top priorities in energy sector. Following India-US nuclear deal in 2005, India entered into collaboration with USA, France, Russia, Australia, Japan and several other countries to build more than dozen nuclear reactors in the coming decades. India is planning to have 14.6 GWe nuclear capacity on line by 2024 and 63 GWe by 2032. It aims to supply 25% of electricity from nuclear power by 2050.

Renewable Energy: Together with nuclear, the government has given top priority to renewables (solar, wind and bio etc.). India has targeted 175 GW of renewable energy generation by 2022 through solar, wind, bio and other renewable means which is five times more than the current capacity. (See Green India under section 1.1 also)

Impacting Research Innovation and Technology (IMPRINT) is a new R&D programme involving 10 leading IITs and universities to address major engineering challenges that the country must address and champion to enable, empower and embolden the nation for inclusive growth and self-reliance. Department of Science and Technology is partnering with Ministry of Education in implementing this program. Ten domains are healthcare, computer technology, advance materials, water, sustainable habitat, security and defense, manufacturing technology, nano technology hardware and environment and climate change.

Mission on Nano Science and Technology (Nano Mission): Building upon the promotional activities carried out as part of the Nano Science and Technology Initiative (NSTI) in the highly promising and competitive area of Nano Science and Technology, the Government of India launched a Mission on Nano Science and Technology (Nano Mission) in May 2007. Recognizing the success of Nano Mission,

[13] http://www.tifac.org.in/index.php?option=com_content&view=article&id=5&Itemid=6
[14] http://www.tifac.org.in/index.php?option=com_content&view=article&id=835&Itemid=1402
[15] http://www.nstmis-dst.org/

the Union Cabinet accorded approval for continuation of the Nano Mission in its Phase-II during the 12th Plan period with an allocation of Rs. 650 crore. The Department of Science and Technology is the nodal agency for implementing the Nano Mission

Fund for Improvement of S&T Infrastructure in Higher Educational Institutions (FIST): In recent years, great concern has been expressed about lack of infrastructure facilities for imparting good quality higher education and conducting advanced research. While the departments in universities and other higher educational institutions had made some impact on the development of teaching and research through their own efforts, a stage had reached where they needed selective strengthening of their infrastructure for post-graduate education and research in emerging areas.

Big Data: Science & Technology – Challenges: Some of the S&T challenges that researchers across the globe and as well as in India facing are related to data deluge pertaining to Astrophysics, Materials Science, Earth & atmospheric observations, Energy, Fundamental Science, Computational Biology, Bioinformatics and Medicine, Engineering & Technology, GIS and Remote Sensing, Cognitive science and Statistical data. These challenges requires development of advanced algorithms, visualization techniques, data streaming methodologies and analytics. DST has taken a big lead in promoting big data. National Super Computing Mission is launched in 2015.

Promoting Space Research: Designing and launching satellites for the country and as commercial venture is given a top priority by the government in 2015. The government allocated nearly a US $ 1 billion in 2016-2017 budget for space research. Following are the various programmes under space research.

- *Operational flights of Polar Satellite Launch Vehicle (PSLV).*
- *Developmental flight of Geo-synchronous Satellite Launch Vehicle (GSLV- Mk II).*
- *Development of heavy lift Geo-synchronous Satellite Launch Vehicle (GSLV-Mk III).*
- *Design, Development and Realization of Communication Satellites.*
- *Design, Development and Realization of Earth Observation Satellites.*
- *Development of Navigation Satellite Systems.*
- *Development of satellites for Space Science and Planetary Exploration.*
- *Earth Observation Applications.*
- *Space based systems for Societal Applications.*
- *Advanced Technologies and newer initiatives.*
- *Training, Capacity building and Education.*
- *Promotion of Space technology.*
- *Infrastructure / Facility Development for space research.*
- *International Cooperation.*

Technology Watch and Foresighting (TWF): Technology Watch and Foresighting (TWF) Division – set up in April 2014 - works towards promoting and nurturing innovations in technology while looking into the future with a definite foresight strategy.

ICT and Software: E-governance and national network for internet connectivity is given a top priority by the government through Digital India Programme (see under 1.1 section)

Agriculture Research and Development: India is set promote Second Green Revolution through National Agriculture Innovation Project which is based on systemic innovation model. Together with Green and White Revolutions, the government has given top priority to Blue Revolution to promote fisheries and aquaculture.

National Health Mission: Several R&D and community linked programmes are promoted in 2015 under Health Mission including Rural Health Mission. Creating additional infrastructure and expanding the reach of public health system is given high priority under National Health Mission.

Science and Engineering Research Board: SERB to promote basic research in science and engineering in frontier areas and material sciences.

Drugs and Pharma research: Development of vaccines and drugs.

Disha Programme for women Science and Technology: Dishis a special scheme to facilitate
the mobility of women scientists. This scheme aims to avoid or reduce difficulties a faced by employed women in mid-career to move from one place of employment to another within in India on account family reasons. Allocations for Consolidation of Research for Innovation and Excellence in Women Universities (CURIE) is also a part of this programme

Biotechnology R&D programmes: Three main focus programmes are creation of 6 centres of excellence in biotechnology for promoting R&D in advance areas; special programme for North Eastern India; and creation of biotechnology parks and incubators.

Defence Research and Development: The lead organization DRDO is working in various areas of military technology, which include aeronautics, armaments, combat vehicles, electronics, instrumentation engineering systems, missiles, materials, naval systems, advanced computing, simulation and life sciences. The new government has given major thrust to PPP for indigenisation and innovation in its R&D programmes in 2015.

The structure, organization and system of India's national innovation system can be characterized as a 'top-down' centralized pattern, particularly with regard to prioritizing research policies and funding. However, it is a model which gives a good deal of research and policy autonomy at the science agency and research laboratory level of functioning once the policies and budgetary provisions are made. Indian research system is dominated by public research funding. The private funding of GERD is less than 30% in 2015-16.

The term regions in India mainly refer to different federal states. Much of the research governance in the states is carried out by the state governments and S&T councils created in most of the 28 states in India. Each state government has institutionalised a ministry of science, technology and education. In some states the S&T ministry is separated from the education portfolio. Much of the R&D is organised under these ministries and coordinated and governed by the State S&T councils appointed by the state governments. In the last three years about only 7% to 9% of GERD is contributed by states, hence it plays only a subsidiary role in the overall national innovation system.

Whilst the national innovation system and GERD is dominated by central government, universities or the academic sector plays a subsidiary role in so far as the research and innovation is concerned. As explained in the section 1.4.3, there over 750 universities with 35,000 affiliated colleges. This sector is the main source of skills and human resources in knowledge-based and high technology sectors of the Indian economy. Even though the higher education sector as a whole contributes more than half of India's S&T output in terms of publications, it accounts for mere less than 5% of GERD.

Within the private business enterprise sector, both Indian and foreign firms have come to occupy a significant position in the national innovation system. There are more than 750 foreign multinational firms which have opened R&D centres in India in the last decade.

The states, which have become pro-active in aiding and complementing the research and innovation policies of the central government, are Karnataka, Delhi, Maharashtra, Andhra Pradesh, Punjab, Haryana, Kerala, Gujarat and Tamil Nadu. It is for this reason that state capitals in these states have evolved as India's major knowledge and innovation hubs. The notable ones are Bangalore, Hyderabad, Mumbai, Pune, Chandigarh, National Capital Region of Delhi and Chennai.

1.4.2 Governance

India's national innovation system is quite intimately integrated with high level political system. Under the overall administrative and executive control of the Prime Minister's Office (PMO), the structure of the S&T system operates in a coordinated and consultative mode. The top level research policy formulation, planning, coordination and advisory role in S&T from a long term perspective (generally keeping five year plans in view) is carried out by three major actors: (i) the National Institution for Transforming India (NITI Aayog), which replaced the earlier Planning Commission; (ii) the Ministry of Science and Technology including the Department of Science and Technology; and (iii) the Principal Scientific Advisor, the Science Advisory Council to the Prime Minister. In 2010-2011 the Prime Minister's Office also set up a National Innovation Council with an advisory role, but after the new government taking over reigns, major functions and the advisory role of this body is taken over by other individual ministries and NITI Aayog thereby leaving it somewhat inoperative.

The PMO and the NITI Aayog represent the powerful top bodies in the governance structure of India's research system. The Second level comprises Ministries in various S&T sectors, industry, finance, economy etc. At this level there are S&T Departments such as the Department of Science & Technology (DST), the Department of Atomic Energy, the Department of Biotechnology (DBT), etc., and science councils such as CSIR, ICMR, and ICAR.

Under the Ministry of S&T, whilst the Departments such as DST control and distribute R&D funds in almost all areas of research, science agencies are devoted to broad areas such as industrial research (CSIR, which houses 38 national laboratories), agriculture research (ICAR), medical research (ICMR) etc. The third level includes the higher education sector and the fourth level consists of the private business enterprise sector with their S&T and R&D labs. This private sector includes both Indian and foreign enterprises.

The Ministry of Human Resource Development (MHRD) governs the sector of education consisting of primary, middle and higher education. Mainly four councils govern the higher education, namely, the All India Council for Technical Education including management; the Medical Council; the University Grants Commission, which governs all public and private universities; and a body, which governs social science research and vocational education and training.

The government's finance ministry has a wide consultative mechanism with which budget formulation is carried every year. Taking into various submissions both by public and private research and innovation actors in the national system, the budget according to stated policies of the government makes budgetary allocations to various S&T and R&D institutions. The budget not only follows certain overarching S&T and innovation policy parameters but in turn also triggers certain policy trajectories with its focus on certain sectors and flagship programmes of the government. For instance, the 2016-17 budget rejuvenated and further strengthened the inclusive growth policies with special attention to agriculture and rural economic regeneration.

The government's public policies on research and innovation and budgetary allocations every year does take into account the expectations, orientations and specific pleas. However, one cannot say that any particular stakeholder from civil society or industry or any other agency can influence the budgetary allocation process. Such stakeholders do influence broad and overarching research and innovation policies to some extent but budgetary exercise is completely immune from such influences.

As depicted in Figure 1, the cabinet headed by the Prime Minister and his Prime Minister's Office in conjunction with the Finance Ministry in 2016 have emerged as the most important actor in giving various policies relating to science, technology and innovation. Most of the flagship programmes listed in section 2.3 have emanated from Prime Minister in the last two years for which various budget allocations have been made by the Finance Minister. The second level of policy making in research and innovation is carried out by various Ministries relating to different S&T sectors.

At the level of policy implementation, various science councils and departments under various ministries such as CSIR, DSIR, DST, DAE, DOS, DBT,etc come to play a significant part. There are a number of laboratories (more than 1000) under these departments and science councils which actually perform research. There are various units and bodies within these departments and science agencies which are entrusted with the evaluation and innovation activities. As in the case of NACC for the higher educational institutions, there is no separate evaluation body for research implementation of policies and projects. Much of the evaluation on various S&T sectors, science departments, science councils and projects is carried out routinely by Comptroller and Auditor General of India and other Parliamentary Committees.

1.4.3 Research performers

The national innovation system is mainly constituted by a) public research system; b) private business enterprise and transnational corporations (TNCs both Indian and foreign); c) higher education institutions (universities and colleges); and d) NGOs and civil society organisations.

a) *The Public Research System (PRS)*: This comprises national laboratories under a dozen of science and technology agencies from space, atomic energy, agriculture, industrial research etc, and in-house R&D laboratories in large public sector enterprises in steel, fertilisers, railways, power, transport and aviation, chemicals, petroleum and energy etc. PRS is India's main innovation system actor as it accounted for 64.4% of GERD during 2012. Out of the total full time equivalent scientific and technical human resources in 2012, 61% work in major science agencies such as CSIR, DAE, DBT and in State government agencies etc, 14% work in universities and 25% in private laboratories. The dominance of PRS in India contrasts with East Asian economies such as Korea and Japan where over 75% of GERD comes from private sources. The role of State governments to GERD is quite marginal.

b) *Private Business Enterprises and TNCs*: This is the second major actor of the Indian innovation system, which accounts for nearly 35.6% of GERD in 2012 and about 25% of total scientific and technical human resources of the country in 2012. In 1990-91, the private sector accounted for 13.8% of GERD. This figure increased to 20.3% in 2001-02 and to nearly 35.6% in 2012. In recent years, the business enterprise sector assumed considerable importance with the global competitive edge of Indian businesses in pharmaceuticals, automotive, software, telecommunications and biotechnology. Whereas the international economic crises created ripples in the US and European markets and industry in so far as the auto and IT sectors are concerned, a more optimistic market scenario emerged in the Indian case. In 2009, in the midst of the crisis, Tata launched the world's cheapest car, the Tata Nano, into the Indian market. The second Indian auto firm, Mahindra & Mahindra also launched its new indigenous model 'Scorpio', a semi-utility vehicle. Another player that will enter to the market in 2012 is Bajaj with its mini car RE60.

The other sector, which witnessed robust growth and expansion, is telecommunications. The Indian telecom market is one of the fastest growing markets in the world. There are more than 950 million mobile subscribers in India and more than 200 million internet users. The third sector witnessing a reasonable growth despite economic crises is India's IT and services industry, which contributes to over 7% of India's GDP in 2014. More than 3 million professionals work in the sector, which generated revenues to the tune of 110bn US$ in 2014.

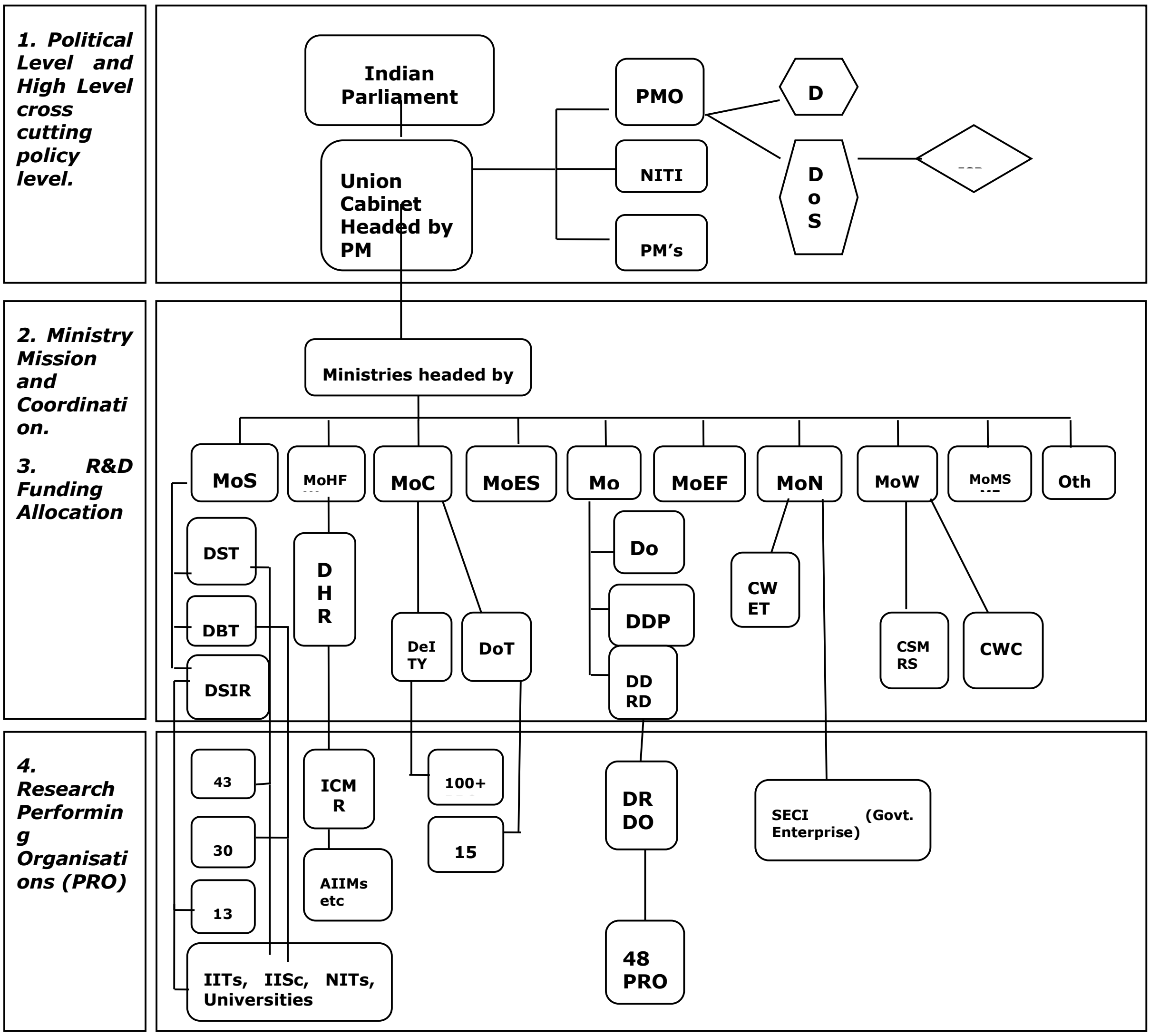
The trend of global R&D investment flows to India is sustained and growing in 2015-16. About 750 global multinational firms operate their R&D centres or laboratories in India. The investments particularly converge in laboratories in Bangalore, Hyderabad, Delhi, Pune and Chennai regions. Bangalore is the preferred destination of foreign R&D centres accounting for 45% of the firms. It is followed by NCR (Delhi) with 22% of the centres. Compared to the situation in the 1980s known as the era of 'adaptive technology' for local markets, in the last few years TNC R&D centres in India are oriented towards 'creative technology' for high-end Indian industry and global markets.

c) *Higher education institutions (HEIs)*: With over 750 universities with 35,000 affiliated colleges, much of the recent dynamism witnessed in the knowledge-based and high technology sectors of the Indian economy is the result of human resources, skills and the knowledge base created in the higher educational sector. However, R&D in HEIs in India is a weak link in India's national innovation system. It accounts for a mere 14% of scientific and technical personnel compared to 61% of total R&D personnel of the country in PRS. Higher education R&D is less than 5% of GERD.

However, universities accounted for over 52% of India's total research publications in 2012-13, which makes the sector a very important knowledge-producing actor of the innovation system. The most eminent and well-recognised HEIs are the 20 Indian Institutes of Technology, 6 Indian Institutes of Management, 12 Institutions of National Importance (such as the Indian Institute of Science and the Tata Institute of Fundamental Research) and about 20 Central Universities (like JNU). Together with these institutions, a tiny proportion of 5% of state-level universities may be considered as India's high-ranking research-based HEIs. By all means, a bulk of nearly 70 to 75% of HEIs are pre-dominantly teaching universities and colleges which are yet to achieve the Humboldtian goal of teaching and research-based institutions. The third mission of innovation is mainly found to operate in IITs. The bulk of Indian universities are yet to institutionalize innovation culture.

d) *Non-governmental research institutions aided by both public and private sources:* This sector plays a very important role in representing the civil society. In the last few years, NGOs begun to undertake substantial policy oriented research relating to science and technology issues. The sector has also come to influence policy decision-making in the country. NGOs are involved in research in topics like environment, ecology, energy, rural development, women and gender, grass root innovations and small technologies research including cottage and micro enterprises.

Figure 1: Governance Organisational Structure of Research & Innovation of India



PM: Prime Minister
PMO: Prime Ministers' Office
SAC: Special Advisory Committee
NITI: National Institution for Transforming India
DAE: Department of Atomic Energy
DoS: Department of Space
ISRO: Indian Space Research Organisation
MoS&T: Ministry of Science & Technology
MoHFW: Ministry of Health & Family Welfare
MoES: Ministry of Earth Sciences
MoCIT: Ministry of Communications & Information Technology
MoD: Ministry of Defence
MoEFCC: Ministry of Environment, Forests and Climate Change
MoNRE: Ministry of New and Renewable Energy
MoWRRDGR: Ministry of Water Resources, River Development and Ganga Rejuvenation.
MoMSMEs: Ministry of Micro, Small and Medium Enterprises**.**
DST: Department of Science & Technology
DBT: Department of Biotechnology
DSIR: Department of Scientific and Industrial Research
DHR: Department of Health Research
DeiTY: Department of Electronics and Information Technology
DoT: Department of Telecommunications
DoD: Department of Defence
DDP: Department of Defence Production
DDRD: Department of Defence Research & Development
CWET: Centre for Wind Energy Technology

CSMRS: Central Soil and Materials research station
CWC: Centre Water Commission
ICMR: Indian Council for Medical Research
AIIMs: All India Institute of Medical Research
IITs: Indian Institute of Technology
IISc: Indian Institute of Science
NITs: National Institute of Technology
DRDO: Defense Research and Development Organisation
SECI: Solar Energy Corporation of India

1.5 Quality of the science base

As the Table shows Indian institutions published 114,449 papers in all areas of science and technology in 2014. According to the SCOPUS database, whilst public research institutions account for 42%, HEIs account for 52% of total publications. The business enterprise sector is a minor actor with just 3% of total publications. Even though Indian HEIs account for a mere 4-5% of GERD they account for more than half of the national scientific publication output.

Table 3 Indian Publications 2010 -2014

Year	Documents	Citable documents	Cites	Uncited documents	%of international collaboration	% from Region	% of World
2010	78,955	74,310	468,902	25,255	17,11	11,53	3.28
2011	95,979	90,199	403,544	36,585	16,19	12,45	3.75
2012	105,279	98,863	294,336	47,956	16,16	13,04	3.98
2013	111,184	10,522	158,914	64,417	16,35	13,01	4.11
2014	114,449	10,078	34,961	95,902	16,36	13,44	4.40

Source: SCOPUS

Even though India's proportion of world science output witnessed steady increase from 3.28% in 2010 to 4.40% in 2014, publications counted per thousand population shows that the country is far behind compared to other countries in 2013. India publications per thousand population stands at 0.08 compared to 0.35 for China; 0.29 for Brazil; and 1.68 for USA. Whereas India's share of international co-publications at 16.2% slightly outpaces China which registered 15.4%, it compares low compared to 31.6% for USA; 25.3% for Brazil; and 38.8% for Mexico. China, India and Brazil stand at par with each other when we examine to see the percentage of publications in the top 10% most cited publications for 2000-2013 years. As expected USA outpaces which stands at 15.03. In terms of the share of public-private co-publications for 2011-2013, India is 0.7%; China 1.0%; and USA 2.8%. Given India's large population, the figures for thousand populations show quite a low proportion in all most all indicators. However, China, India and Brazil seem to be at the same level when we examine the average relative citation at around 0.7 compared to USA at 1.38.

As already noted in section 2 on funding, India R&D intensity somewhat stagnated over the last decade below 0.9% and more over university sector accounts for staggeringly low level of less than 5% of GERD again during the last decade ending 2016. On the other hand, China's R&D intensity almost doubled from 1% to nearly less than 2% in the last decade. This is one of the reasons for India's weaker performance in science output comparable to particularly China.

Table 4: India in the Sphere of Publications

Indicator	India	EU average
Number of publications per thousand of population (2013)	0.03	1.43
Share of international co-publications (2013)	16.2%	36.4%
Number of international publications per thousand of population (2013)	0.01	0.52
Percentage of publications in the top 10% most cited publications	6.03 (2000-2013)	10.55
Share of public-private co-publications (2011-2013)	0.7	1.8%

1.6 Main policy changes in the last five years

Main Changes in 2011

Main changes in 2012

The 12th Five-Year Plan (2012-17) inlcuding "Inclusive Innovation" and the Inclusive Innovation Fund (IIF) About USD 320 million (INR 5 billion), or some 10% of the total, was raised by July 2012.

Main changes in 2013

The National Skills Development Agency (NSDA) was created in June 2013

The National Innovation Council (NInC) (created in 2010) with a mandate to formulate a roadmap for innovations for 2010-20, It introduced the New Science, Technology and Innovation Policy in 2013, which focuses on inclusive growth.

Main changes in 2014

The Prime Minister announced the programme *Make in India*. It is structured in a way to promote investment, innovation, enhance skill development, protect intellectual property and build manufacturing in the country. The program is steered by the Department of Industrial Policy and Promotion (DIPP), Ministry of Commerce and Industry.
The Ministry for Skill Development and Entrepreneurship (earlier Department of SkillDevelopment and Entrepreneurship notified in July 2014) has been set up in November 2014 to give fresh impetus to the Skill India agenda and help create an appropriate ecosystem that facilitates imparting employable skills to its growing workforce over the next few decades.

Main changes in 2015

Digital India programme launched. Its goal is to deliver governance through mobile phones and to expand the internet connectivity throughout the country. There is also the goal to deliver services relating to health, education and social welfare through 'information highways'.

Sources: including from National Policy on Skill Development and Entrepreneurship 2015
http://www.skilldevelopment.gov.in/assets/images/Skill%20India/policy%20booklet-%20Final.pdf
OECD Science, Technology and Industry Outlook 2014

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2. Public and private funding of R&I and expenditure

2.1 Introduction

Government S&T and R&D institutions, by and large, dominate India's National Innovation System (NIS) comprising public and private actors and agencies performing R&D activities. The GERD as proportion of GDP has been relatively stagnating over the last decade, particularly in the last four years, fluctuating between 0.88% and 0.90%. As is evident from Table 1, whilst the EU average is around 2%, India is spending little less than half of this EU figure. In so far as the overall R&D intensity trend is concerned, there has not been any significant change except that there has been only a marginal increase in the proportion of BERD/GDP between 2011 and 2015. However given the fact that India's economy grew at an average of 6.5% per year between 2011-12 and 2015-2016, registering a growth rate of 7.3% for year ending 2016, there has been an increase about 15% in the absolute national GERD in this period. In real terms there has not been any budget cut for GERD or interruption of research schemes. As shown in Table 5, the allocated budget for 10 leading science agencies increased by 63% between 2015-16 and 2016-17.

Over the last decade and a half, particularly in the last few years, India has become one of the attractive destinations for multinational firms to set-up R&D centres or labs. According to a report from the Chambers of Commerce and Industry, 870 multinational firms have established R&D centres.[16] According to a recent study in 2012[17], About 271 global TNCs operate their R&D centres or laboratories in India. The investments particularly converge in laboratories in Bangalore, Hyderabad, Delhi, Pune and Chennai regions. Bangalore is the preferred destination of foreign R&D centres accounting for 45% of the firms. It is followed by NCR (Delhi) with 22% of the centres. Much of India's FDI in R&D has gone to major cities such as Bangalore, which have developed a functional local innovation eco-system and knowledge hubs. Compared to the situation in the1980s known as the era of 'adaptive technology' for local markets, in the last few years TNC R&D centres in India are oriented towards 'creative technology' for high-end Indian industry and global markets.

The government in its Science, Technology and Innovation Policy, 2013 (STIP 2013), announced that it would spend 2% of GDP on R&D through PPP model. The Modi government, which took over the reins in 2014, reiterated this commitment but there is a slow movement in this direction. For instance, this point bears out if we compare the allocations of budgetary provisions to major science agencies between 2015-16 and 2016-17 as shown in Table 2.

The distribution of budgetary allocations to different science agencies in the last three years reveals that whilst strategic science sectors (nuclear energy, space and defense) witnessed 50% to 120% increase, other science agencies witnessed only marginal increase of 10 to 15%. The Ministry of New and Renewable Energy witnessed tremendous boost in the last three years whose budgetary allocations was increased by 1000%. India set for herself a very ambitious target of achieving 100GW (solar); 60GW (wind): 10GW (biomass); and 5GW (small hydro) renewable energy by 2022. Government priority to promote renewable and clean energy is clearly evident from the budgetary allocations in 2016.

Policy thrust is also given to National Biotechnology Strategy as the Department of Biotechnology (DBT) which witnessed nearly increase 28% in budgetary allocations this year in 2016 compared to last two years. As the head of DBT observed, there is an emphasis for the 'creation of new infrastructure. India already hosts several genomics

[16] Battelle India and Federation of Indian Chambers and Commerce, India's Emerging Competitiveness as Destination of Global R&D', Knowledge Paper, New Delhi, India, 2015

[17]

research institutes, such as the Institute of Genomics and Integrative Biology (IGIB) and the National Institute of Plant Genome Research, both in New Delhi, and the National Institute of Biomedical Genomics near Kolkata. The DBT's strategy aims to create five more centres, each dedicated to a different field, including drug discovery, marine biology and infection, as well as several centres of excellence based on narrower, high-priority areas such as genetically modified organisms, vaccines and marine bio-products'.[18]

Table 5: Basic indicators for R&D investments

Indicator	2011	2012	2013	2014	2015*	EU average (2015)**
GERD (as % of GDP)	0.87	0.88	0.88	0.88	0.90***	2.03 (2014)
GERD (Euro per capita)	9.50	9.55	No data	No data	No data	558.4(2014)
GBAORD (€m)	8698			10794***		
GBOARD as %of GDP	0.62	0.62				
R&D funded by GOV and HEIs (% of GDP)	0.56	0.56				
R&D funded by PNP (% of GDP)	No data	No data	No data	No data	No data	
R&D funded by BES (% of GDP)	0.30	0.31				
R&D funded from abroad (% of GDP)	0.004	0.004				
R&D performed by HEIs (% of GDP)	0.006	0.006				
R&D performed by GOV (% of GDP)	0.56	0.56				
R&D performed by BES (% of GDP)	0.30	0.31				

Note: Actual data for 2013 to 2015 not available due to late issue of R&D statistics by DST, Min of S&T
N.B. This section should be updated once the latest EUROSTAT otherwise OECD data are available - December 2015. Please describe any key developments.
* The 2014 data will be added once the December 2015 data will be released
The EU28 average data will be provided by **IPTS in December 2015.
*** Estimated

Table 6 Budgetary Allocations in INR (euro) millions

Science Agency	2014-2015	2016-2017
Department of Atomic Energy (DAE)	77,000	116,825*
Defence Research & Development	62,997	135,938

[18] *Nature News*, 26 February 2016 (http://www.nature.com/news/india-s-budget-keeps-dream-of-genomics-hub-alive-1.19469)

Ministry of Earth Sciences	13,365	16,724
Ministry of New & Renewable Energy	5,549	50,358**
Department of Science and Technology(DST)	28,980	44,702
Department of Scientific & Industrial Research (DSIR)	34,000	40,628
Department of Biotechnology	14,172	18,200
Department of Space	58,260	75,091
Department of Health Research	9,320	11,448
Department of Agricultural Research & Edn.	48,840	66,200
Total	**352,483 INR (4712 euro)**	**576,114 INR (7701 euro)**

Source: Ministry of Finance, India, Budget Papers 2015 and 2016
Note: *Includes budget for operating nuclear power stations; ** includes money from a clean energy levy now known as Clean Environment Cess.

2.2 Funding flows

2.2.1 Research funders

Finance Ministry being the apex government body to formulate and allocate budgetary provisions for S&T and R&D to various ministries, the next level of fund allocations for research is carried out by various science departments or science agencies (for instance DST, DAE, DSIR etc.,) operating under various ministries. Some of these leading science agencies and science departments are identified in Table 2. It may be pointed out that apex finance ministry in its budget allocations allocates over 80% of research funds each year. Hence, what is left for second level allocation is a small portion of remaining 15 to 20%.

Research funds in Higher Educational Institutions (HEIs) such as universities and leading teaching and research institutions is allocated by Ministry of Human Resource Development at first level and then by the University Grants Commission at the second level.

With regard to policy level mechanisms for allocation of research funds, these are governed and priorities given according to government policies. For instance, the government has laid a top priority to renewable and clean energy in its policies due to energy security and climate change related issues. Given this policy priority, one can see the increase of research funds to Ministry of New and Renewable Energy by whopping 1000% in the last three years. Similarly, the government policies have given top priority to space and atomic energy and hence these agencies attracted between 50 to 100% increase in the allocation of research funds in the last three years. With regard to different types of institutional modalities adopted for distribution of research funds by the main nodal agency, Department of Science and Technology, Ministry of Science and Technology, following types may be identified as practiced in 2016.

Types or modality of funding

Broadly two types of funding can be conceptualized or categorized under the public funding arrangements. One is the block grants or institutional funding given to public research science councils or large organisations, universities and other agencies and labs under the government in the federal structure of India. The other is the project or programme based funding.

Block grants or Institutional funding

Institutional support here refers to public research institutes or organisations, universities and other agencies under the government. These funds are given for carrying out research at the discretion of respective institutions. Of the total governmental support, about 64.4 % is earmarked for institutional support in 2011-12. India's major scientific agencies and departments under central government account for 48.3 %; 7% allocated to State government based science agencies; little more than 5% is accounted Public Sector Enterprises; and 4.1% by higher education through the University Grants Commission and All India Council for Technical Education.

It may be noted that the money is allocated based on research priorities as indicated by national policy discourse and advisory systems at the level of DST and Science Advisory Council. There is no performance assessment for allocating budgets in the institutional support mode to science agencies and other institutions such as UGC. Only a small portion of the total money allocated to DST, UGC, AICTE, etc, mostly in the oriented basic research and applied development projects are allocated on competitive basis. In the DST, the Science and Engineering Council is the main nodal agency for allocating R&D money on competitive bidding of projects submitted by various national labs and universities. For coordinated projects relevant concerned department or science agency and the DST evaluate the competitive bids.

Project Based Funding

The major source for project based funding in India comes from DST. DST support of project funding is for advancing knowledge in basic research; achieving excellence in science and engineering; promotion of innovation in selected areas; encouragement for industrial partnership in projects under engineering and technology; training of manpower for future requirement and encouragement to young scientists and students. The total estimated figure for 2015-16 for project based funding is INR 22790 million. It may be pointed out that this money is given to three categories of project based funding, namely, research programmes; research networks or coordinated projects and 'bottom-up' projects.

a) Research Programmes: Science and Engineering Research Board (SERB) of DST which was rechristened in 2011 is one major source of project based funding for advancing scientific research. Scientists and faculty from both national laboratories under different science agencies and higher education sector are eligible to these funds every year. Even private industrial and business enterprise professionals in collaboration with scientists in public research institutions can be considered. All projects through SERB are subjected to a peer process and the priorities given include science excellence and quality, advancement to knowledge in newly emerging areas in science and engineering. The major focus of funding goes here to nanoscience and technology, drug discovery, green chemistry and technologies and low carbon emission and life sciences. It is estimated that 40 to 45% of total project funding is given to research programmes in 2015-16.

b) Networks or coordinated projects: In 2015-16 the DST has given considerable support to strengthening scientific research networks through supporting coordinated projects covering some twelve science agencies. The second source of coordinated project support funding comes from the

Ministry of Agriculture, Ministry of Environment and Forests and Indian Council of Medical Research.

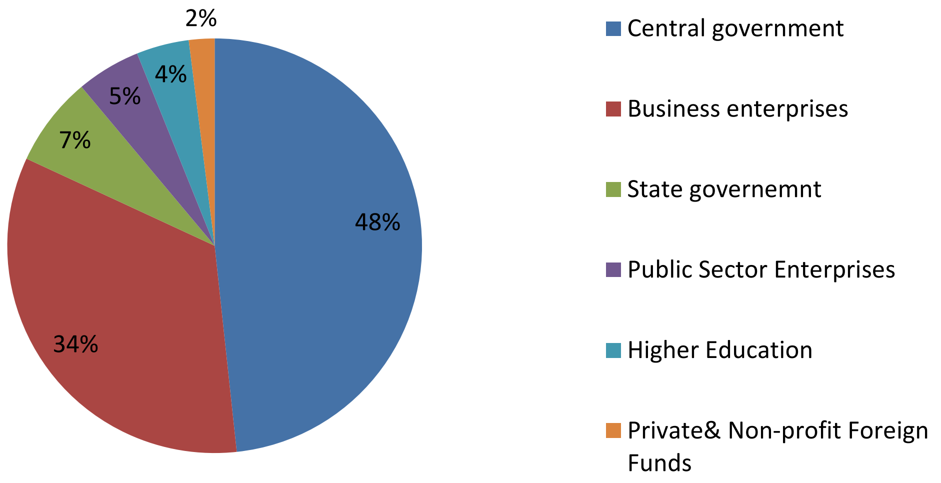
c) Bottom-Up Projects: DST is allocating around 25% of total project based funding for supporting projects in 147 departments or research groups in higher education sector, projects devoted to the development scientific research base in the North-East region of India, for sophisticated analytical instruments, strengthening science base in research groups and individuals, among other aspects.

d) International Projects: India is participating in FP7 projects on the European Union's International Thermonuclear Experimental Reactor (ITER) nuclear fusion energy project; and the satellite based navigation system, Galileo Project (European version of USA's Global Positioning System). India and the European Union also decided to embark on joint scientific projects, including those in strategic fields, after holding their first ministerial science conference in the Indian capital, New Delhi, on 10 February 2007. India also signed a pact with the EU to participate in the proposed Facility-for-Antiproton-and-Ion-Research (FAIR) project aimed at understanding the tiniest particles in the universe. In 2015-16 DST allocated INR 1070 million to international cooperation related projects.

e) Other Modes of Funding: In this category of funding the most important mode of funding which deserves mention is the funding available from extra mural source of funding for research students or scholars at post-doctoral or individual scholars on special themes. Such funding is routed through the UGC and mainly science agencies such as CSIR. While UGC also funds more than 15 inter university centres of excellence in different universities, DST has a small window of funding for such programmes or centres. TIFAC under DST has source of funding for encouraging start-up firms which are basically a form of co-funding between the industry partner involved and the professional from public research institutions. For the development of weaker sections of Indian society, the Ministry of Human Resource Development (MHRD) and UGC have very good sources of funding for under privileged sections (called scheduled tribes and scheduled castes in India) with scholarships. DST, MHRD, CSIR and UGC have also a good source of funding to encourage women in science and technology. DST has also launched a programme to encourage women entrepreneurs in S&T related fields.

2.2.2 Funding sources and funding flows

Figure 2: Sources of GERD 2011-2012*



* Estimations based on 2010 data. Source: Department of Science and Technology, Government of India

Sources of funding

In 2011-12 the gross expenditure on research and development (GERD) in India is INR 72,6000 (8698 euro) million.[19] As depicted in the figure, national funds for R&D flow from five sectors namely, government, business enterprise, higher education, private non-profit and from Abroad. The two main sources of R&D funds are: government (INR 46, 7544 (5633 euro) million or 64.4%); and business enterprise (INR 25, 8456(3113 euro million) or 35.6% including 2% or INR 1,4520 (174 euro) million from private and non-profit organisations coming from foreign sources) in 2011-12. Out of INR 46, 7544 (5633 euro) millions of government sources of funds for R&D, 48.3% is from central government; 7% from state governments; 5% from public sector enterprises; and 4.1% from higher education sector, of the total INR 25, 8456 (3113 euro million) or 35.6% from the business enterprise sector, a tiny proportion of 2% is accounted from abroad or outside India from private non-profit organisations.

In India government administration dominates for the dispersal of government R&D funds, which are as follows:

a. The first is the central government, which is the predominant source of R&D funds and accounts for around 48.3% of funds.
b. The second is the business enterprise section which accounts for 35.6% (including 2% from abroad and private non-profit sources)
c. The third is the State government, which accounts for 7% of GERD*.*
d. The international agencies including aid agencies do not play any significant part in national R&D scenario. They account for less than 2% of GERD.

Even though the Government's R&D statistics for 2016 yet to be published, on the basis of discussion with officials at the Department of Science and Technology and yearly budget statements of the government, it may be pointed out that there is no major change in the balance of sources of funds in the last three years. One major change that

[19] Estimated figure @ 1EUR=61.01 INR as on 12 Oct 2013).

has come about in the last one year is that various ministries other than the ministry of science and technology have also generated a good demand for research projects in rural development, ICT and telecommunications, roads and railways, water and rivers ministry and industry ministry. The new government has launched a series of projects and schemes (see below) from these ministries, which generated demand in R&D institutions both private and public.

2.3 Public funding for public R&I

Various schemes to stimulate research and innovation in India

There are a number of schemes, which are operated by DST and DSIR under the Ministry of Science and Technology. The Table below lists some of the important ones, which are in force as of 2016.

Table 7: Some Important Research Schemes

Name of the scheme	Operated by	Main remarks
Small Business Innovation Research Initiative	DBT	To provide support for early stage, pre-proof-of-concept research in biotechnology by industry
Technology Systems Development Programmes (TSDP)	DST	To convert proof of concept/idea/initial process to commercialization across industry sectors
Technology Refinement and Marketing Programme (TREMAP)	TIFAC, DST	For pushing the innovative technologies, up the commercialization cycle, towards market utilization.
Promoting Innovations in Individuals, Start-ups and MSMEs (PRISM)	DSIR	To support individual innovators
Technology Development and Utilization Programme for Women (TDUPW)	DSIR	To encourage women for technology development
Patent Acquisition and Collaborative Research and Technology Development (PACE)	DSIR	To encourage Indian industries to acquire patent from India or abroad.
Centres of Excellence and Innovation in Biotechnology (CEIB)	DBT	The scheme is for promotion of excellence in interdisciplinary science and innovation in specific areas of biotechnology.
Biotechnology Parks and Incubators	DBT	To facilitate product advancement and innovation through the development of biotechnology industrial cluster and to produce biotechnologists and entrepreneurs
Research and Innovation Schemes Introduced since 2014-2015		

Stimulating Investments in Biotechnology and Textiles through Clusters	DBT	Development of biotechnology clusters in Faridabad and Bengaluru; and 6 mega clusters in Textiles at Barelly, Luncknow, Surat, Kutch, Bhagalpur, Mysore and one in Tamil Nadu
National Biotechnology Development Strategy	DBT	To regulate biotechnology and encourage excellence
National Policy on Skill Development and Entrepreneurship 2015	Ministry of skill Development	To encourage start-ups and young entrepreneurs
Deendayal Upadhyaya Gramin Kaushal Yojna (2015)	Ministry of Skill Development	For providing training in skills for rural youth
Atal Innovation Mission	National Institute for Transformation of India (NITI Ayog)	The mission will be an Innovation Promotion Platform involving academics, entrepreneurs and researchers and drawing upon national and international experiences to foster a culture of innovation
Self-Employment Talent Utilization (SETU) Scheme	NITI Ayog	To encourage self-employment and start ups
Consolidated Foreign Direct Investment Policy	Department of Industry	Encourages foreign investment in the country for creating domestic capital, technology & skills development.

In an earlier section 2.2.1, we have explored different types of funding, namely, project based, block funding and other types. Even though there has not been any major change in the block funding, the project based research grants have become more competitive in the last few years. The new government, which has come to power in 2014, has generated demand for research in various sectors of economy. Some estimates from the Department of Science and Technology, Ministry of Science and Technology indicate that the balance between block funding and project funding is dominated by the former by 85%. The project funding is likely to assume significance as several flagship programmes (See section 1.2) of the government have begun to allocate funds on competitive basis. Much of the project based funding from DST is based on peer review process and expert consultation basis. Some of the programs offering project based funding to stimulate research and innovation in public sector and other agencies are as follows.

<u>Public Programmes Which Stimulate Research in Public & Private Research and Innovation</u>

In the year 2015, the Modi government has identified number of National Flagship Programmes or Missions, which entail S&T, R&D, innovation and resources including financial and human skills. Each flagship programme involves a group of multiple sectors and a heavy coordination through a group of ministries including science and technology. These flagship programs are:

	India's Flagship Programs	Budget allocation in 2016-17 INR million (Million Euros)
1	Make in India (generic program spread over various ministries)	

2	Digital India	2287 (305)
3	Skill India (including startup India)	115000 (1537) for five years
4	Green India –clean energy (including Ganga cleaning)	72500(969)
5	Smart cities and urban Transformation (AMRUT programme)	122800(1641)
6	Clean India	90000(1203)
7	Creating New Infrastructure	70 0000(9358)

2.4 Public funding for private R&I

2.4.1 Direct funding for private R&I

The Seven flagship programmes listed in 1.2 above are open to the private sector. All projects selected involving research and innovation under the seven flagship programmes are awarded on competitive basis. The new government since 2015 has brought in considerable transparency in award of projects across various sector of economy, particularly in ICT and telecommunications, mining, infrastructure and railways.

- The government has initiated several mechanisms to ease doing business in India, especially aiming at foreign investors. Some of the main provisions are as follows:
- The Prime Minister's Office has set up a unit and various mechanisms are implemented in various other ministries for 'single window' clearances;
- Set up exclusive commercial divisions in the courts to help ensure the speedy resolution of commercial disputes;
- Introduce a Public Contracts (Resolution of Disputes) Bill to streamline the institutional arrangements for the resolution of such disputes;
- Appoint an expert committee to draft legislation to ensure that regulatory approval can be granted expeditiously;
- Maintain and update an e-business portal which integrates 11 regulatory permissions relating to doing business in India at one source (this portal is now active);
- Progressively expand the 'visas on arrival' scheme from 43 countries to 150 countries; and
- Remove distinctions between the different types of foreign investments (foreign portfolio investment (FPI) and foreign direct investment (FDI)). Currently the aggregate foreign investment permitted in a sector has separate caps for FPI and FDI. It is proposed that all types of foreign investment will be captured under a composite cap, which will provide Indian companies greater flexibility when seeking foreign investment and investors more clarity and certainty when investing.

Funding schemes and projects under the seven flagship programmes involve very little fundamental research. Applied and development research and innovation seems to be the main thrust in most of the projects. All most all the projects under seven flagship programmes encourage public-private cooperation.

Start-ups Funding Schemes

The government in January 2016 unveiled a 19-point action plan for start-up enterprises in India - an all-inclusive action plan to boost such ventures that would boost employment generation and wealth creation (see further details on start-ups in section 3.2 on 'Framework Conditions'.

Most funding schemes are bench marked against comparable experiences in other countries particularly in EU, China, USA, Australia and Canada. Technology Information Forecasting and Assessment Council (TIFAC) of DST has launched some specific programmes and schemes such as home grown technology[20], advanced composites[21], bioprocess and bio-products[22] etc. DST and DSIR, the major science departments of the Ministry of Science and Technology have also launched several programmes on technology development, drugs and pharma research and technology development board, etc[23]. All these programmes are conceptualized with the basic premise of promoting public-private partnership for generating market-driven projects with potential applications in areas such as chemical, bio-medical, pharma and vaccines, transportation, tourism etc.

The relation between public procurement and endogenous based innovation process in India goes back to the Nehruvian industrial policy of self-reliance and import substitution in science and technology. The previous government under Dr Manmohan Singh brought in Public Procurement Bill in 2012. Modi government in the budget speech of 2015-16 sought to further revise and introduce various measures in the 2012 Bill. The present government introduced various flagship programmes (See section 2.3) which are intimately related to public procurement and innovation via Make in India programmes. India's defence ministry, which is now seen as among the top five buyers of defence equipment in the world, has adopted several measures of public procurement to boost innovation in India. The present government is in the process of revising the 2012 Bill. Hence it will be futile to analyse the Bill, which is under discussion by the Finance Ministry.

In section 2.2 and 2.3 various provisions for government's direct support to public and private R&D are already discussed. The private business enterprises and industry in India has come to play an increasing role since 2014-15 under the policy promotion of PPP mode for research and innovation. This has particularly assumed importance in the light of government's seven flagship programmes mentioned in section 2.3 along with the procurement policies in the defence industry.

2.4.2 Indirect financial support for private R&I

There is no systematic analysis which exists on the total indirect financial support to private R&D in India. However, according to some estimates obtained from the Department of Science and Technology, New Delhi, indicated that out of Rs 17,0380 million expenditure on R&D in 2012 less than 0.25% can be taken as the approximate figure for indirect financial support to private R&D. It is most likely that this figure has escalated to nearly 0.5% of GERD in 2015.

There is 100% write off of revenue expenditure on R&D under of IT Act for firms; 100% write off of capital expenditure on R&D in the year the expenditure is incurred (land is not included); weighted tax deduction of 175% (to the sponsor) for payments made to approved national laboratories, universities and IITs or a specified person (that is salaries to scientists), with a specific direction that the said sum shall be used for scientific research under a programme. This is allowed by the Section 35(2AA) of the IT Act.[24]

There is the provision of 'weighted deduction of up to 125% which is available for contributions made to any company engaged in scientific research. However, the following conditions must be satisfied in order to claim the deduction. For this the company must be registered in India; the main object of the company must be scientific R&D; the Chief Commissioner of Income Tax must approve the company'[25]. There is also

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[20] http://www.tifac.org.in/index.php?option=com_content&view=article&id=48&Itemid=204;
[21] http://www.tifac.org.in/index.php?option=com_content&view=article&id=29&Itemid=41
[22] http://www.tifac.org.in/index.php?option=com_content&view=article&id=65&Itemid=96
[23] http://www.dst.gov.in/technology-development

[24] http://www.dsir.gov.in/forms/irdpp/Application%20for%20R&D.pdf
[25] http://www.ey.com/Publication/vwLUAssets/EY-worldwide-randd-incentives-reference-guide/$FILE/EY-worldwide-randd-incentives-reference-guide.pdf

'weighted deduction of up to 125% available for contributions made to approved institutions (e.g., research associations, universities, colleges that undertake research in social science or statistical research) to be used for research in social sciences or statistical research'[26].

In so far as the indirect financial support to business research and innovation is concerned, the government until 2016 has given tax incentive of 200% tax deduction on research and development for in house for various private firms particularly sought out by the pharma and biotechnology firms. From 2016 budget proposal by the finance ministry will reduce this tax incentive to 150% from 2017 to 2020 and then to 100% from 2021. This is a major change that has come about in the last three years. Other indirect tax benefits given by DSIR, ministry of science and technology are[27]:

i) Customs duty exemption to in-house R&D units established by corporate companies, other than a Hospital for capital equipment and consumables needed for R&D;

ii) Central excise duty exemption to in-house R&D units established by corporate companies, other than a Hospital for capital equipment and consumables needed for R&D;

iii) Central excise duty waiver for 3 years on goods designed and developed by a wholly owned Indian company and patented in any two countries out of India, USA, Japan and any country of European Union ;

iv) Exemption from customs duty on imports made for R&D projects funded by Government in industry;

v) Goods specified in List-28 (comprising of analytical and specialty equipment) for use in
pharmaceutical and biotechnology sector allowed being imported duty free.

As noted earlier, there is a 100% tax deduction programme for three to five years for start-ups approved before 2019 under Start-up India scheme. There is a definition of start-ups under which a budding entrepreneur with a turnover of less than INR 250 million can avail tax breaks and other benefits for a five-year period. This extends to a cross section of industry from software to manufacturing in various sectors.[28] The Department of Electronics and Information Technology provides tax incentives for firms located in Special Economic Zones. 'Incentives are available for companies engaged in providing R&D services under a service arrangement by way of export of services to a foreign principal. Such companies may set up their units in SEZs in order to secure the tax benefits. SEZ units engaged in export of goods and services from 1st April 2006 onwards are eligible to claim a 15-year, phased tax holiday (refer table below) on all export linked profits earned'[29]. The quantum of deduction to SEZ unit is 100% for 5 years; 50% for next 5 years; and 50% of export profits if they find their way back into the SEZ or for buying machinery etc. There are exemptions from customs duty on the import of capital goods and inputs; exemptions on the procurement of good domestically; exemption in the service tax on the services consumed within the SEZ;

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[26] Ibid.
[27] Ibid.
[28] http://articles.economictimes.indiatimes.com/2016-02-23/news/70874299_1_tax-breaks-startups-capital-gains-tax-exemption
[29] http://www.ey.com/Publication/vwLUAssets/EY-worldwide-randd-incentives-reference-guide/$FILE/EY-worldwide-randd-incentives-reference-guide.pdf

and incentives for interstate transaction of goods and purchases.[30] There is a cess of 5% for import of technology under foreign collaboration.

The government under the Jawaharlal Nehru National Solar Energy Mission allows Domestic Content Requirement for solar panels manufacturing (solar PV cells and modules) for 350 MW for a plant of 700 MW. In other words 50% of the technology cum manufacturing is required from local sources so as to boost the solar industry in the country, which has a target of 100 GW of power from solar by 2022.

All private or public firms, which exploit and generate revenues from patents coming out of the country, are given tax concessions in the 2016-17 budget announced by the finance minister. Tax incentives both direct and indirect are given a high importance in the country by the government and adopted quite robustly. US has recently through WTO regime questioned the indirect incentives given to solar sector, which is under dispute currently.

2.5 Assessment

The structure and governance of the public R&D system can be characterized as a 'top-down model', particularly with regard to prioritizing research funding based on political policy priorities manifested in yearly budget plans. The system that is in operation gives a good deal of research and policy autonomy at the science agency and research laboratory level of functioning. Public or government research funding dominates India's national research system. Whilst the public research science agencies in space, nuclear energy, defence, industrial research in pharma and chemical, among other sectors have emerged as important actors in the innovation system, the R&D in business enterprise (BE) sector has begun to play an important role in the last five years.

India's R&D intensity is below 0.9% and has been relatively stagnant over the last decade. The government is committed to increase it to 2% of GDP. More than 60% of GERD is consumed by the strategic sectors of nuclear energy, space and defence and what is left for other sectors is staggeringly low. The overall R&D intensity is also quite low compared to China, South
Korea, Japan and OECD members, which spend between 2.2 to 4%. The most striking feature of India's R&D structure is that the country despite having more than 700 universities is spending less than 5% of GERD on R&D in higher education.

Some of the negative features of national R&D funding structure may be summarised as follows:

- Medium level of funding (R&D/GDP) is a constraint to infuse new research and innovation capacities
- Government commitment to double R&D/GDP (2%) – implementation process is very slow
- The quantum of project based funding is low compared to block grants
- The quantum of funding devoted to civilian R&D is low compared to strategic R&D
- Research intensity in academic sector is very low (about 5%) compared to government research agencies (64.4%) in GERD
- Slow implementation of IPR in universities as bill is still pending in the Parliament
- Compared to OECD and other emerging economies, business enterprise R&D proportion of GERD is of low level.
- R&D tax incentives lack penal underpinning to ensure firms undertake R&D rather than quality control, technical activities etc.
- Public – Private Partnerships in R&D and Academy – Industry partnerships are underdeveloped

[30] http://www2.deloitte.com/content/dam/Deloitte/in/Documents/tax/in-tax-india-guide-2015-noexp.pdf

- Weak research accountability and evaluation in public research system
- Linkages between public procurement and R&D institutions and universities very weak.

Some of the positive features may be summarised as follows:

- India’s rapidly growing middle class, urbanisation and expanding markets coupled with highly skilled and low wages makes an attractive destination to FDI in R&D
- High level of knowledge and technological capabilities in pharma, auto, software, aerospace and satellite design and launching has enabled India to become competitive at the global level. India’s capabilities in reverse engineering and production of generic drugs are very high.
- Software, professional, medical and engineering services with high skilled workers at low wages is a major attraction to world markets.
- Seven flagship programmes initiated by Modi's government has generated considerable research and innovation demand across a range of sectors.

The funding pattern and government policies are by large geared to increase the share of business enterprises in the GERD. The R&D incentives structure and indirect tax policies are beginning to have an impact on the business enterprises both Indian based and transnational based R&D centres in the country. From an overall perspective it may be said that the funding system is geared towards improving the research and innovation eco-system and increase the quality of research. The major problem for India’s R&D funding is the slow movement in the 2% of GDP for GERD which has been committed by present and previous governments.

3. Framework conditions for R&I

3.1 General policy environment for business

According to World Bank indicators for 'Doing Business' for 2016, India stands at 130th Rank out of 189 countries. According to this report, there is an improvement in the conditions of doing business in India compared to 2015 when India was ranked 134.[31] India according to World Bank Report has to catch up with other countries in making policies conducive and ease for doing business. In 2016, China was ranked 84; Russian Federation 51; Mexico 38 and Bangladesh 174.

The government issued a document called "Assessment of State Implementation of Business Reforms" on 14th September 2015.[32] The report captures the findings of an assessment of reform implementation by States, led by DIPP, Ministry of Commerce and Industry, Government of India with support from World Bank group and KPMG. This assessment has been conducted to take stock of reforms implemented by States in the period of January 1 to June 30 2015 based on a 98-point action plan for business reforms agreed between DIPP and State/UTs and rank them according to the ease of doing business. The government in 2015 has taken several steps towards 'ease of doing business' in India. These are:

- Process of applying for Industrial License (IL) and Industrial Entrepreneur Memorandum (IEM) has been made online and this service is now available to entrepreneurs on 24x7 basis at the eBiz website. This had led to ease of filing applications and online payment of service charges.

- 20 services are integrated with the eBiz portal which will function as a single window portal for obtaining clearances from various governments and governmental agencies.

- Notification has been issued by the government to limit number of documents required for export and import to three.
- Ministry of Corporate Affairs has introduced an integrated process of incorporation of a company, wherein applicants can apply for Director's Identification Number (DIN) and company name availability simultaneous to incorporation application.

- The Companies (Amendment) Act 2015 has been passed to remove requirements of minimum paid up capital and common seal for companies. It also simplifies of other regulatory requirements.

- A comparative study of practices followed by the States for grant of clearance and ensuring compliances was conducted through M/s Accenture Services (P) Ltd., and six best practices were identified. These were circulated among all the states for peer evaluation and adoption. The study has also identified important bottlenecks faced by industries and important steps required to improve the business environment in States.
- Application forms for Industrial Licence (IL) and Industrial Entrepreneur Memorandum (IEM) have been simplified

The average period for insolvency resolution in India is 4.3 years, significantly higher than that of South Asia region (2.6 years) and that of Organisation for Economic Co-operation and Development (OECD) high-income countries (1.7 years). There are number of firms which have already defaulted and this has become a very big debate in

[31] http://www.doingbusiness.org/data/exploreeconomies/india/

[32] http://dipp.nic.in/English/Investor/Ease_DoingBusiness/EoDB_Intiatives_11December2015.pdf

India in 2016 with the failure of Kingfisher Airlines. The Reserve Bank of India, Securities and Exchange Board of India (SEBI) have formulated very strict norms as of March 2016 to make defaulters of loans to bank as categorised will not be able to raise loans again from the market. There are norms which impose heavy penalty to owners of firms which have defaulted.

3.2 Young innovative companies and start-ups

The Prime Minister inaugurated an Action Plan for Startup India and Standup India on 16 January 2016 which included a series of policies and measures to encourage and boost start-up activity in the country. Various measures are as follows:

- The government announced INR 10 0000 million fund for 4 years from 2016 to promote start-ups in India.
- A single point of registration for start-ups. A new portal will simplify registration of firms, approvals etc.
- A self-regulatory scheme to bring in self-certification subject to verification of government later on. Self-certification relates to complying with government norms on paying gratuity, provident fund management, pollution norms etc. This process is introduced to reduce regulatory liabilities on the part of government.
- A fast track for filing in patents by Start-up foundations, individuals and other potential professionals who wish to file patents at reasonable costs.
- Tax exemption for 3 years on capital gains for start-up as given currently to Venture Capital investments.
- Startup India hub with hub and spokes model with central and state governments, Indian and foreign VCs, angel networks, banks, incubators, legal partners, consultants, universities and R&D institutions. The hub will assist start-ups in obtaining financing, and organise mentorship programs to encourage knowledge exchange.
- The Central Government, State Government and PSUs will exempt start-ups in the manufacturing sector from the criteria of "prior experience/ turnover" as long as they have their own manufacturing facility in India, and have the requisite capabilities and are able to fulfil the project requirements to be eligible for support measures.
- Faster exit for start-ups. This facilitation window is created for start-ups which are experiencing difficulties such as losses etc. Some guidelines are available with the Department of Industrial Policy and Promotion.
- The Atal Innovation Mission (See section 1.3 for more details) will establish sector specific incubators and 500 'Tinkering Labs' to promote entrepreneurship, provide pre-incubation training and a seed fund for high-growth start-ups. Three innovation awards will be given per state and union territory, along with three national awards, as well as a Grand Innovation Challenge Award for finding ultra-low cost solutions for India.
- The government will identify and select ten incubators, evaluated on pre-defined Key Performance Indicators (KPIs) as having the potential to become world class, and give them Rs.10 crore each as financial assistance to ramp up their infrastructure.

Some other measures and promotional avenues for Start-Ups directed at youth are listed below:

(i) Start-up India hub: An all-India hub will be created as a single contact point for start-up foundations in India, which will help the entrepreneurs to exchange knowledge and access financial aid.

(ii)

Register through app: An online portal, in the shape of a mobile application, will be launched to help start-up founders to easily register. The app is scheduled to be launched on April 1.

(iii) Patent protection: A fast-track system for patent examination at lower costs is being conceptualised by the central government. The system will promote awareness and adoption of the Intellectual Property Rights (IPRs) by the start-up foundations.

(iv) INR 10,0000 (1 336 Euro) million fund: The government will develop a fund with an initial corpus of INR 2,5000 (334 Euro) million and a total corpus of INR 10,0000 (1 336 Euro) million over four years, to support upcoming start-up enterprises. The Life Insurance Corporation of India will play a major role in developing this corpus. A committee of private professionals selected from the start-up industry will manage the fund.

(v) National Credit Guarantee Trust Company: A National Credit Guarantee Trust Company (NCGTC) is being conceptualised with a budget of INR 5000 (66 Euro) million per year for the next four years to support the flow of funds to start-ups.

(vi) No Capital Gains Tax: At present, investments by venture capital funds are exempt from the Capital Gains Tax. The same policy is being implemented on primary-level investments in start-ups.

(vii) No Income Tax for three years: Start-ups would not pay Income Tax for three years. This policy would revolutionise the pace with which start-ups would grow in the future.

(viii) Tax exemption for investments of higher value: In case of an investment of higher value than the market price, it will be exempt from paying tax

(ix) Building entrepreneurs: Innovation-related study plans for students in over 5 lakh schools. Besides, there will also be an annual incubator grand challenge to develop world class incubators.

(x) Atal Innovation Mission: The Atal Innovation Mission will be further strengthened and expanded to boost innovation and encourage talented youths.

(xi) Setting up incubators: A private-public partnership model is being considered for 35 new incubators and 31 innovation centres at national institutes.

(xii) Research parks: The government plans to set up seven new research parks, including six in the Indian Institute of Technology campuses and one in the Indian Institute of Science campus, with an investment of Rs 1000 million each.

(xiii) Entrepreneurship in biotechnology: The government will further establish five new biotech clusters, 50 new bio incubators, 150 technology transfer offices and 20 bio-connects offices in the country.

(xiv) Dedicated programmes in public schools: The government will introduce innovation-related programmes for students in over 5 lakhs schools.

(xv) Legal support: A panel of facilitators will provide legal support and assistance in submitting patent applications and other official documents.

(xvi) Rebate: A rebate amount of 80 percent of the total value will be provided to the entrepreneurs on filing patent applications.

(xvii) Easy rules: Norms of public procurement and rules of trading have been simplified for the start-ups.

(xviii) Faster exit: If a start-up fails, the government will also assist the entrepreneurs to find suitable solutions for their problems. If they fail again, the government will provide an easy way out.

There are a number of funding schemes and funding policy measures listed in 2.3. Most of these measures and schemes are directed at young innovative companies. Particular mention may be made of Atal Innovation Mission, Self-Employment Talent Utilization Scheme and Small Business Innovation Research Initiative.

There are several policies and instruments to encourage cooperation and knowledge sharing for SMEs. The most important among such knowledge clusters are more than 45 Software Technology Parks of India spread all over the country covering prominent cities such as Bangalore, Chennai, Hyderabad, Delhi NCR, Pune, Calcutta etc.

The Start-up India policy initiative by the government has announced to create 500 tinkering labs with 3D Printers in universities, the setting up of 35 new incubators in institutions with 40: 40: 20 investment ratios by central, state and private enterprises and the setting up of 7 new research parks modelled on IIT Madras, India's current only S&T Park in the premises of a university. The government has also announced the creation of 5 new bio-clusters, 50 new bio incubators, 150 technology transfer offices and 20 bio connect offices for coordination and facilitation of activities related to innovation.[33]

[33] http://indiatoday.intoday.in/education/story/start-up-india-stand-up-india/1/573128.html

3.3 Knowledge transfer and open innovation

Historically speaking, most leading universities in India have been performing the roles of teaching and research so as to make an impact on the society and economy. Traditionally consultancy and sponsored research between industry and university was prevalent. However, the feature of coupling teaching/research with innovation and at the same time forging university–industry relations (UIR) including with public research institutes and various actors and agencies in the national systems of innovation has come into sharp focus only in the last decade in India. In 2013 more than 70% of total India's publications (Web of Science) came from university sector but unfortunately there is no data available on academia-industry co-publications.

In 2013 less than 8% of universities were considered as research based universities according to a study. In universities, wherever some form of research base exists, consultancy and sponsored research are the highly preferred modes of knowledge transfer. With the exception of six old IITs, IISc Bangalore, IIMs and a small number of central and private universities in Delhi, Mumbai, Chennai, Calcutta, Hyderabad, Pune, Noida etc, none of the universities have established innovation, incubation and entrepreneurship centres. On the whole it may be observed that there is a lack of innovation culture in the Indian university sector. A study in 2009 covered 460 firms and tapped 735 professors and scientists in four industrially developed states, namely Maharashtra, Karnataka, Tamil Nadu and Delhi.[34] In this study only 17% of 460 firms reported universities as important source of knowledge. Even in the case of public research institutes (PRI), only 21% of firms relied on it as source of knowledge. Further, only 3% of firms said that universities are the sources for new projects.

UIR has been mainly the domain of IITs in India. A study of IITs has shown that much of UIR are manifested in sponsored and industrial consultancy mode. Further this study revealed that the value of consultancy and sponsored research between 2000 and 2011 increased from 17% to 43%.[35]

At the national and centralised level involving the Department of Science and Technology and the Department of Scientific and Industrial Research (See section 1.3 and 2.3), on various innovation policy measures and instruments initiated to promote R&D cooperation project between public/academic/not for profit sector research institutions and enterprises. For instance, DSIR has initiated several research programmes[36] to forge science and industry links. Two notable programmes under DST are Home Grown Technologies and Technology Development Board programme. Home-grown Technologies programme is administered through the Technology Information and Forecasting and Assessment Council (TIFAC) under DST. Projects are supported to commercialise Indian processes and technologies with loans at low interest rates compared to market and equity participation. Similarly, DST also administers the programme through the Technology Development Board. All these programmes demand partners in universities and business enterprises and have succeeded in forging university-industry cooperation. Tata's Nano car and hepatitis B vaccines commercialization were supported by DST through Technology Development Board.

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[34] Joseph, K.J and Vinoj Abraham, University – Industry Interactions and Innovation in India: Patterns, Determinants, and Effects in Select Industries', Seoul Journal of Economics, 22(4), 2009

[35] See Krishna, V.V and Swapan Patra, 'Research and Innovation in Universities in India' in N.V Varghese and Garima Malik (eds) India Higher Education Report, UK: Routledge, 2015

[36] Some of these are: Industrial R&D Promotion Programme; Technology Development and Innovation Programme; Technology Development and Demonstration Programme; Technopreneur Promotion Programme; Technology Management Programme; International Technology Transfer Programme; International Technology Transfer Programme; and Technology Development & Utilization Programme for Women.

In recent years there has been a growing interaction between the Indian Institutes of Technology (IITs) and the industry at the Laboratory level. This has manifested itself in different forms. For instance, Tata Consultancy Services (TCS) and the Indian Institute of Technology (IIT), Chennai, launched an Academic Centre of Excellence and a user-oriented M.Tech programme in Computational Engineering. The establishment of incubation units at IIT Delhi (TBIU), IIT Bombay (SINE), IIT Kanpur (SIIC) and IIT Kharagpur (TIETS) are relatively recent developments in aiding knowledge transfer and circulation. Incubation and enterprise creation or what is known as spin-offs has come into prominence and sharp focus in the IITs via incubation units. The Table presents some recent developments in five IITs.

The involvement of the business-enterprise sector in the governance of HEIs and PROs has acquired considerable importance in the last decade. The leading Indian business enterprise houses are represented through their founders or CEOs in the leading universities and PROs. For instance, Indian industrialists such as Mr Ratan Tata (Tata Group), Mr Mukesh Ambani (of Reliance Industries), N.R. Narayanmurthy (INFOSYS), Keshub Mahindra (Mahindra Group) – to take only few names prominently figure in the governing bodies of various public research institutions and universities.

Table 8: Incubation, Spin-offs and Entrepreneurial Infrastructure at IITs

Institution	Incubation Unit/year established	No. of Incubator /spin-offs	Prominent Areas	Other Infrastructure
IIT Bombay	Society for Innovation and Entrepreneurship (SINE); 2004	As of January 2014 about 16 companies are in SINE and 34 companies are either graduated / exited/ acquired/folded-up	IT, computer science, electronics, design, earth sciences, energy & environment, electrical, chemical, aerospace	Entrepreneurship Cell
IIT Delhi	Technology Business Incubation Unit (TBIU); 1999	About 30 Companies	computer science, electrical , chemical engineering, inter-disciplinary areas, life sciences, chemistry, IT, BT	Foundation for Innovation and Technology Transfer (FITT) Entrepreneurship Development Cell
IIT Kanpur	Innovation and Incubation Centre (SIIC); 2000	Since its inception, it has incubated and mentored 53 companies of which 26 have already graduated	IT, design, weather insurance, navigation systems	Entrepreneurship Cell; Electronic and Animation Cell; Small Scale Industry Cell

IIT Kharagpur	Technology Incubation and Entrepreneurship Training Society (TIETS); 2006	About 84 companies are under incubation	IT; computer science; ceramics; energy	Entrepreneurship Cell ; STEP; Biotechnology Park; TTG, research and innovation park
IIT Madras	IITM Incubation Cell (IITM-IC); 2013	Over 30 companies are incubated	IT; computer science; physics	C-TIDES; Research Park

STEP: Science and Technology Entrepreneurs Park;

* TTG: Technology Transfer Group;

* C-TIDES: Cell for Technology Innovation, Development and Entrepreneurship Support;

* Entrepreneurship Cells are a body managed by students' initiative *

IIT Madras is the first university campus in India to establish university-driven Research Park (IITMRP). It is an independent company under Section 25 of the Companies Act promoted by IITM and its alumni. IITMRP invites and promotes research-focused companies to set up units and leverage IITM's strong scientific and research expertise. IITMRP currently houses about 55 companies, including ten incubated by IITM. So far in 2013 it has incubated over 30 companies. These ventures are leading the dissemination of world-class technology to solve some of rural India's most difficult problems such as power, water and education. Under the Bio-Incubator Support Scheme (BISS), IIT M established the Bio-Incubator (BI), which has incubated 2 companies. [37]

3.4 Assessment

Two major shifts in the framework of research and innovation can be seen in the last two years. The government has given a renewed policy focus to solicit the participation of business enterprises sector through Public-Private Partnerships (PPP) in almost all sectors of economy including the social and S&T sectors. All flagship programmes (see section 1.2) not only create considerable demand side spectrum of innovation but the government is partnering private business enterprises to achieve goals set under these programmes. Closely related to this is the policy focus on attracting the FDI in R&D by creating enabling research eco-system. Currently there are more than 1000 foreign MNCs (more than 250 are FORTUNE-500 global firms), which have opened up R&D centres in India. Four most important sectors of private business enterprises are IT software, pharmaceuticals, telecommunications and automobiles. IT software service and other related exports in 2016 touched the figure of US $ 150 billion and accounted for 7% of India's GDP. India's two major auto firms Tata and Mahindra launched indigenous new models sedans, semi utility vehicles and trucks. Indian automobile production increased from 5.3 million units in 2001-02 to 20.3 million units in 2011-12. Nearly 19% were cars and the rest two and three wheeler vehicles. In 2012, the Indian automotive industry provided direct employment to more than 320,000 people and contributed 5% of India's GDP. The other sector which witnessed robust growth and expansion is the telecommunications. Indian telecom market is one of the fastest growing markets in the world in 2016 in terms of subscribers it stood at 1.02 billion. In the last two years the new government under Modi has opened up India's space, nuclear energy and defence requirements to private business enterprises.

Secondly, there is a move towards project based and mission mode funding compared to the existing focus on institutional funding. All flagship programmes (see section 1.2) have specific targets and missions to achieve. Together with mission mode approach, the

[37] See http://www.incubation.iitm.ac.in/about-us/ecosystem

accountability and transparency factor has come into force as there is increasing participation of business enterprises.

The priorities for demand side innovation policies are set and driven by not one but several ministries and departments which are dealing with new flagship programmes. For instance, the public procurement which poses demands on innovation can come from any ministry from rural development, urban development to defence. The most popular tools currently in use are tax incentives for firms and business enterprises investing in R&D; special schemes and policy measures which are meant to attract business enterprises to commercialise indigenous technologies; public procurement in defence and strategic sectors, urban development department and other ministries responsible for roads and transportation etc.

There are three pathways opening up for EU under various programmes and European R&D firms interacting with India. These are:

(a) A good deal of research output has been produced in the EU-India cooperation projects, both in the form of joint research papers and patents in several S&T areas. Much of the research output and knowledge already generated exists in fields such as water, environment, biotechnology, ICT, health, energy, among others. There is a good ground to say that EU-India cooperation projects have generated research and innovation potential relevant to India's main flagship programmes like Clean India, Green India, Smart Cities, Digital India and several other areas such as infrastructure and transportation. In other words, there is an enormous amount of demand existing to convert and realize the research and innovation potential within India's new policy priorities. Dr João Cravinho former head of EU mission in New Delhi in 2015 already expressed his positive sentiments pointing to smart cities, digital India, cleaning Ganga etc. The impact of EU-India S&T projects and cooperation will be determined by creating institutional mechanisms and instruments for promoting linkages and innovation in the coming decade.

(b) This above point leads to the expanded role of the European Business and Technology Centre (EBTC) in India, which is already involved in biotechnology, energy, environment, transportation, and IPR areas.

(c) Beyond the EU-India S&T cooperation projects, a new pathway has already emerged for various European countries and India partnerships based on private firms, business enterprises and public enterprises. SNCF, France and Indian Railway have tie-ups for developing high-speed railways. The Indian Essel Group signed a Memorandum of understanding (MoU) with FeCon GmbH, Germany a subsidiary company of Wind and Sun Technology GmbH for transfer of wind and solar energy technology to Indian partners. Mr. Ashok Agarwal, CEO, Essel Infra projects, pointed out that the partnership will help the company deliver on its commitment to produce 12,500 MW of solar energy and 4,000 MW of wind energy in India in the coming year. Fraunhofer, a German S&T institution and Vikram Solar, an Indian firm, will collaborate to establish a solar academy in India to impart technical knowledge, expertise, and practical training in solar energy systems. There is immense innovation potential that exists to be exploited in half dozen new flagship programmes.

4. Smart specialisation approaches

India being one among the fastest growing economies in the world is increasingly becoming more and more important in the global world economy. At times when the western countries are reaching saturation in their markets and China facing economic downturn, Indian economy is showing huge market and business potential in terms of investments and business development. This is also evident from the fact that Indian economy had a growth rate of 7.6% in 2015-2016 which shows a fairly decent growth rate amidst the global economic slowdown. [38]

The measure of India's R&D expenditure to GDP is 0.88% as per 2011-12 data.[39] Most of the developed countries of the world spend around 2% of their GDP in terms of expenditure on Research and Development. However, India is still aspires to reach the expenditure on R&D at 2% level of GDP and it has been emphasized in the recent policy discourses related to Science, Technology and Innovation.

Furthermore, even with still considerably less amount of GERD in terms of GDP, India is emerging as one among the 5 emerging global R&D hotspots destinations which includes Brazil, South Africa, Eastern Europe, India and China.[40] This has been largely catered with some recent past decisions and current policy measures. To boost the R&D activity in the economy and to make the process more 'inclusive' some specific policy measures have been adopted, which provides high emphasis on Research & Development & Innovation for the larger goal of accelerated economic growth. The policy measures in the recent times by Narendra Modi government like 'Make in India', 'Start-up India', 'Digital India' 'Skills India', 'Clean India', 'Green India', 'Smart Cities/Urban Development' and 'Infrastructure development' are being seen as the key specialised strategies for accelerated socio-economic development of India. These flagships programs are related to various crucial sectors for the economy like technology, innovation, manufacturing, start-ups, entrepreneurship, services, defence, energy, environment, food, health, education and skills.

Furthermore, the Research and Innovation systems operate at three levels comprising of National System of Innovations, Regional Systems of Innovations and Sectorial Systems of Innovations. Good deal of discussion on various parts of National Innovation System is covered in the previous sections. We would discuss Regional Systems of Innovations (RIS) here. RIS includes the components of science, technology and innovations at the level of state which is being activated and managed by the state governments in terms of policy dispensation, worked by organisations within a cluster, knowledge infrastructure including universities and institutions related to research and innovation.

4.1 Governance and funding of regional R&I

Governance and funding of Regional Research and Innovation mechanism comes under the ambit of Regional system of innovations which relates to federal states of India and their governing mechanisms for Science, Technology and Innovations. The state governments have a department of science & technology under which they have a special body called the state council of science and technology. Some of the pioneer states in taking lead in following a clear cut objective of science & technology and working with related specific policy measures were Karnataka, Delhi, Maharashtra, Andhra Pradesh, Punjab, Haryana, Kerala, Gujarat and Tamil Nadu. Because of this, some of the prominent cities which have emerged as hubs of science, technology and innovation are NCT Delhi, Chandigarh, Pune, Mumbai, Bangalore, Hyderabad, and Chennai.

38 http://indiabudget.nic.in/es2015-16/echapter-vol2.pdf

39 http://digitalrepository-nstmis-dst.org/files/stats/2011-12/Full_Text_2011-12.pdf

40 http://zinnov.com/global-rd-service-provider-ratings-2015-2/

Furthermore, in terms of funding mechanism for regional research and innovation mechanisms we find that the federal states of India in terms of their share in GERD was 7.3% as of 2009-10 statistics.[41] The state governments have their own budgeting and financing mechanism for research and innovation. For example the state government of Maharashtra in which the city of Mumbai is located has a unique body called 'Rajiv Gandhi Science and Technology Commission' which works has special body for providing overall support for science, technology and innovation in the state.[42] Among the many objectives of the commission providing financial support is one important objective. Furthermore, most of the state councils of science and technology as autonomous bodies under department of science and technology in the states have their own mechanisms of financial support for research and innovation.[43]

As mentioned earlier in section 1 and 2, some of the flagship policy thrust areas of the current government is 'Make in India' and manufacturing, services, start-ups, entrepreneurships, infrastructure, health, food, education and skills generation. Out of these, priorities are given more to manufacturing, services, entrepreneurship, skills, environment (Clean and Green India projects), smart cities and infrastructure development. The major chunk of investments is being prioritised in following programs which also links S&T, R&D, Innovation and Business development. So these flagships programs such as *Make in India, Digital India, Start-Up India & Stand-Up India, Skill India, Green India, Clean India, Smart Cities* and *Infrastructure Development* are prioritised because of the fact that these will cater to industry and industrial development which would become one of the prime movers for economic growth of the country. These flagship programs are implemented at the regional level by different states of India. In some cases the political and federal divide between the central government and state govern*ment* hampers the process of this programs and its implementation.

Note: More details on flagship programmes are given in section 1.2

Geographical development level of research and innovation policy in India could be understood with two perspectives. First, being the percolation of the national policies of science, technology and innovation and its impact on federal states across India. Second, policies and specific state government measures in relation to research and innovation. From a geographical perspective, the STI policies are formulated by the central government and funding is streamlined from the centre which leaves out only a marginal scope at the regional level.

Furthermore, specific policy measures related to national science, technology and innovation is being catered and administered by central ministry of science and technology. All these policy measures from past till now have worked and catered to the development of national systems of innovations but also percolate its impact in the regional scale of innovation development.

R&D contribution of Indian states towards national share of GERD is very less, 7.3% in 2012.[44] Nevertheless states have their own departments of science and technology and also autonomous bodies called *state council of science and technology.* For example some of the states which are better placed in research and innovation map of the country like Karnataka, Kerala, Delhi, Maharashtra, Tamil Nadu and Andhra Pradesh have very specific science, technology and innovation policy mechanisms. For example the state of Maharashtra has specific commission called *Rajiv Gandhi Science and Technology Commission* which specifically at the state level tries to use science and technology for better socio-economic development of its people.[45]

41 http://digitalrepository-nstmis-dst.org/files/stats/2011-12/Full_Text_2011-12.pdf
42 https://rgstc.maharashtra.gov.in/
43 Ibid.
44 http://digitalrepository-nstmis-dst.org/files/stats/2011-12/Full_Text_2011-12.pdf
45 https://rgstc.maharashtra.gov.in/

Some of the specific policy measures to promote regional linkages

National Policy on Skill Development and Entrepreneurship 2015[46 47] : The government under the larger policy framework of economic and industrial development came with a specific policy measure related to skill development and business entrepreneurship. The *National Policy on Skill Development and Entrepreneurship'* was formally approved *o*n July 1st, 2015 by the union cabinet. This policy in terms of promotion of connection of local actors is related to the emphasis upon the larger eco-system creation within the domain of education, skills training, filling the classic gap of demand & supply, socio-economic empowerment and connection of all this to the wider umbrella of entrepreneurship and innovation. So, as per the official documents of this policy, there are four major areas which bring and shows how different actors come together in the larger framework of entrepreneurship and innovation eco-system and also forms major policy linkages to *Skills India, Start-up India* and *Make in India*.

- The first is related to the renewed emphasis on solving the problem of encouragement for education and skills training participation.

- Second is the emphasis on addressing the problem of demand and supply gap of skills required and skills supplied. There are both problems in terms of quality and quantity of skills; there is always a sense of dissatisfaction from the industrial sector that they do not get the desire skilled workforce both as per qualitative and quantitative measures. The role of industry and government approved skills certification also comes into play where the *National Skill*

- Thirdly the target group in terms of socially and geographically disadvantaged sections of society are to be given priority. This brings the notion of inclusive economic development. Here the role of civil society based organisations working in education and skills' training comes into picture.

Self-Employment and Talent Utilisation (SETU) [48]

This policy scheme under the ambit of *Skills India* and *Start-up India* is specifically targeted towards business start-ups and entrepreneurship in the technology led business areas. The SETU program which means *Self Employment and Talent Utilisation* is mainly aimed to promote entrepreneurship through start up loan schemes initiated by government both at the central and regional levels. The main thrust is related to self-employment generation by using education and skills learned in technical and vocational fields. This SETU program would work in close association with the Atal Innovation Mission (AIM) for building a platform for encouragement and motivation for innovation hubs, start-ups and entrepreneurship.

Atal Innovation Mission (AIM)[49]

AIM is one of the policy schemes related to innovation entrepreneurship under NITI Agog. Atal Innovation Mission with its aim of promoting, catering and nurturing innovation entrepreneurship in the country would bring in variety of stakeholder like entrepreneurs, academics and researchers into the platform of innovation entrepreneurship. AIM in association with SETU (Self Employment and Technology Utilisation) scheme would try to incorporate and make inclusive the wider gamut of innovation entrepreneurship eco-system. This would bring a large number of Indian youths into the domain of educational and skills training, entrepreneurship motivation, socio-economic empowerment for disadvantaged sections and bringing women in the field of technology entrepreneurship. With this it would create a large and inclusive

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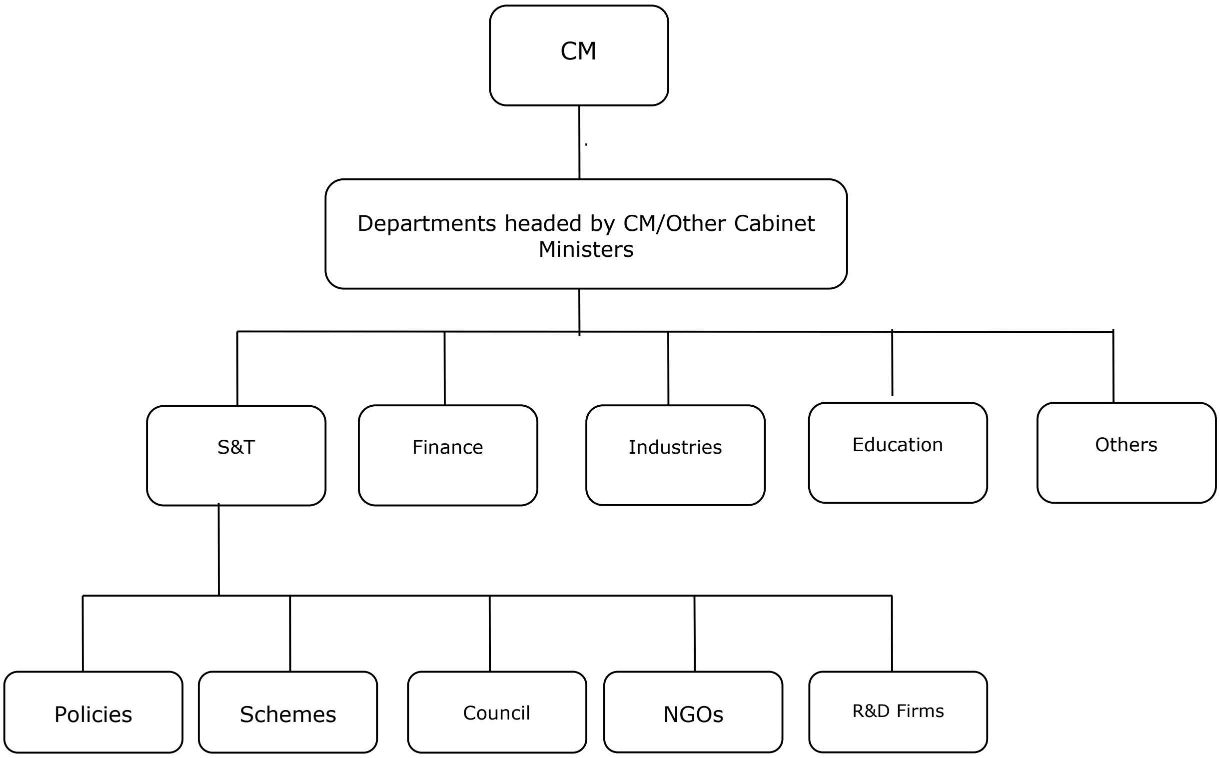
[46] http://pib.nic.in/newsite/PrintRelease.aspx?relid=122927
47 http://pibphoto.nic.in/documents/rlink/2015/jul/p201571503.pdf
48 http://niti.gov.in/content/setu.php
49 http://niti.gov.in/mgov_file/report%20of%20the%20expert%20committee.pdf

ecosystem of which would incorporate education and skills, talent utilisation, self-employment, entrepreneurship and start-ups, linkages to experts, knowledge sharing and financial support.

Figure 3: Diagram of State Research and Innovation Governance Mechanism in India.



4.2 Smart specialisation approaches

Smart specialisation approaches which in EU relates to process of helping various stakeholders and actors to connect together in the process of guidance, training, mutual learning, access to data and information and to participate in the programs for strategy and policy formulations, could be contextualised in the Indian scenario with various platforms which the government of India has created for connecting local actors and stakeholders in the process of research and innovation.[50]

In the Indian context, this is related to the crucial aspect which the government is trying to accomplish by leveraging ICTs penetration in the country for connecting various actors and stakeholders in the process of research and innovation. As the measures of national programs and mechanisms for research & innovation needs to be related and brought to the regional level which in India are the states, the governments' major push is to provide a network which provides data and information for all government measures in general and research and innovation in particular. For this, one of the most important way through which government has connected more than 1500 universities, research institutions, libraries, laboratories, healthcare and agricultural institutions is through *National Knowledge Network (NKN)* formulated and approved in year 2010.[51] The crucial aspect which is strategically important in the NKN network is that, it not only connects national and regional actors and stakeholders in the process of knowledge, research and innovation, but it also connects them to international research platforms which help in international knowledge dissemination.[52] Furthermore, another interesting and relevant aspect of NKN and its role in connecting various actors and stakeholders which includes state government websites is by using the effectiveness of high speed connectivity of multi-gigabit network.[53]

[50] http://s3platform.jrc.ec.europa.eu/
[51] http://nkn.in/about
[52] Ibid.
[53] Ibid.

However, the NKNs relevance and scope now has become more crucial and important as the current government is majorly pushing for digital services and connectivity with help of its flagship program called *Digital India.* The main goal of *Digital India* is to provide specifically digital access of government services to citizens but is also aimed to provide relevant information and data to various others stakeholders like foreign investors, interested firms to start business, to participate in other government measures like *Make in India, Clean India, Skill India* and *Clean India* and for connecting with relevant groups and people in the process.[54] The inclusive e-Governance platforms' through which government is imparting data, information and knowledge related to economy in general and also about specific policy measures related to research & innovation is the (www.mygov.in) platform.[55] It is a key measure which is relevant for local actors & stakeholders. With help of integration of multiple platforms in MyGov platform various services like access to (data.gov.in) platform for open access to government data, DeiTY (Department of Electronics & Information Technology) for digital infrastructure, innovations platform of (innovations.mygov.in) for innovation and *Swachh Bharat* platform for clean India program, government is providing an inclusive and integrative platform for various services important in the process of research & innovation.

Furthermore, other important factors which are working as the super structure base of the digital push and connectivity is rate and diffusion of ICTs with respect to mobiles and internet users. As per the latest press release of TRAI (Telecom Regulatory Authority of India) the total number of mobile wireless users stands at 1 billion (1,010.89 Million users) in India.[56] Furthermore, faster pace of internet connectivity and uses in India which is expected to reach the figure of 506 million users by 2017 is yet another reason for digital connectivity is being pushed forward.[57] This gigantic amount of mobile connectivity in India shows that the ratio of mobile connectivity to the total amount of population which is 1.2 billion has been drastically narrowed down. This is being used by the government as major factor to push for digital infrastructure for people for providing access to various services and schemes. This is also related to the fact that the rise of smart phones in India has been very fast and India with 204.1 million smart phone users is in 2nd place in total smart phones users after China (624.7 million).[58] The use of smart phones has also been largely related to the faster access of data, information and knowledge being very crucial in the process of research & innovation.

Furthermore, considering this important resource base of smart phone users in India, governments both in the central and state level have created various mobile apps for android, iOS and windows platforms to connect actors and stakeholders. Many apps related to government services is provided through a single platform called e-Gov apps store (http://apps.nic.in/) which aims to integrate public and private collaboration with faster means to access to information and knowledge. This platform has a repository of 52 applications encompassing 26 different sectors of the economy which are important for research, development and innovation.[59] With these fast and up-to date measures government is trying to connect and integrate the larger eco-system which is enabling in the process of research & innovation.

Techpedia, an initiative at Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI) in collaboration with National Innovation Foundation, DST, aims at putting the problems of micro, small and medium enterprises, informal sector, grassroots innovators and other social sectors on the agenda of the young technology students across the country. Techpedia.in already has 140 000 technology project documented by 350 000 students from 500 colleges and universities

54 https://mygov.in/
55 https://mygov.in/
56 http://www.trai.gov.in/WriteReadData/WhatsNew/Documents/Press_Release_No_15.pdf
57 http://www.iamai.in/sites/default/files/annual_report/AnnualReport2014-15.pdf
58 http://indiainbusiness.nic.in/newdesign/index.php?param=newsdetail/10367
59 Ibid.

in India in its data bank. National Innovation Foundation, DST in collaboration with Honey-Bee Network, Ahmedabad, Gujarat, has an innovation and technology databank of grass root innovations of more than 100 000 ideas. Some of the smart methodologies used in these programmes relate to crowd sourcing, informal ICT based social networks and volunteer network which identifies and feeds into the data bank.

science and technology, R&D and innovation policies and its future perspectives. See section 1.3 on the two major exercises on foresight by TIFAC.[60]

Some of the policy initiatives which have been taken in the past and also recently reflect the glimpses of '*quadruple helix*' type of linkages of variety of stakeholders in science, technology and innovation policy frameworks. Certain examples can be the *'Biotech Strategy – II, 2015'*, *'Atal Innovation Mission'*, *'National Policy on Skill Development and Entrepreneurship, 2015'*. The '*Biotech Strategy-II, 2015*' mentions about a regulatory body which would incorporate multiple stakeholders in the area of biotechnology development by bringing civil society, farmers, consumers and scientific community together.

Furthermore, '*Atal Innovation Mission*' which talks about creating an eco-system of innovation also incorporates variety of stakeholders from national and regional level connecting people from academia, skills training, entrepreneurship, investment markets, government and civil society into the platform of innovation. The '*National Policy on Skill Development and Entrepreneurship, 2015*' also mentions about the creation of wider connection of 'quadruple helix' type of linkages between number of stakeholders ranging from government, human resource training, research and development, business and enterprises and also civil society in making the process of diffusion of skills training more inclusive.

It could be said that in the formulation of *Science, Technology* and *Innovation Policy,* 2013, the role of Internet, mobile penetration and citizens' participation through social media platforms has come to play an important role. All important major research and innovation policies seek all stake holders' participation before they come to be recognised as policies. For instance, the reformulation of IPR policy in 2016, environment and climate change related measures and Net neutrality measures adopted by the government were open to people's participation. In 2016 the Prime Minister inaugurated the Start-up Stand up India scheme after a national wide consultations and submissions from various stake holders. Even at the regional state level, a variety of stakeholders such as scientists, science students, science and technology entrepreneurs and civil society forms important part of policy making. The process of using information and citizens feedbacks which could be understood from the perspective of e-Governance and especially Indian government's portal called www.mygov.in which is nodal web platform of government of India for engaging citizens in the process of policy making. Some of recent statistics shows that in this portal there are 1.87 million registered members, 173,520 submissions from members on different tasks and 2.63 million comments by members on 499 discussion themes.[61]

Technology Information, Forecasting and Assessment Council (TIFAC) a body under the department of science and technology is related to different foresight and scenario excursuses conducted for

4.3 Regional linkages to economic competitiveness

There are incentives such as tax holidays, venture capital support and seed capital on easy loan basis for firms and researchers in the software related SMEs both to cooperate internationally and become important players in the global value chain. There are also more than 40 Indian Software Technology Parks where infrastructure and high speed connectivity to global communications are given at concessional terms. More than 9000

60 http://www.tifac.org.in/index.php?option=com_content&view=article&id=52&Itemid=213
61 https://mygov.in/

software firms operate out of such software parks. Similar is the case with emerging 'bio-valleys' in Bangalore and Hyderabad. Similarly Indian chamber of commerce and confederation of Indian Industry in partnership with government have a number of schemes initiated in 2015 and 2016 for SMEs to enable them to take part in the global value chains. These are in tourism, hotel, leisure, fashion, travel and various other sectors.

The larger social, political and economic impact of science and technology policy in India needs to be assessed and discussed. This has been one of the policy goals of the *Science, Technology & Innovation Policy, 2013* mentioning about the role of public awareness and public accountability of the Indian STI sector. It says that "*Mechanisms for assessing the performance of the national STI enterprise through an autonomous and robust evaluation system, which includes social scientists, will be established. The national science academies will be accorded a major role in this endeavour of public accountability".*[62]

However, NSTMIS (National Science Technology Information Systems) does collection, collation, analysis and dissemination of data and information related to science and technology, R&D and innovation in terms of economic measures. This is measured in terms of GERD (Gross Expenditure on R&D), BERD (Business Expenditure on R&D), state level expenditure on R&D which is in a way reflects the impact of national and regional level effectiveness of R&I policy measure.[63]

Research and innovation policies related to telecommunications are monitored and evaluated by Telecom Regulatory Authority of India. Policies on GM technologies are monitored and evaluated by Genetic Engineering Approval Committee (GAEC), Parliamentary Committees and various civil society groups such as Centre for Science and Environment.

4.4 Assessment

As discussed in earlier sections, the government initiated various policy measures and flagship programmes such as *Make in India, Digital India, Skills India, StartUp India* and *Clean India* in the last two years. Most of these are medium term programmes with at least 3 to 5 years duration. It would be too early to discuss about their impacts and results in terms of assessment.

Furthermore, in terms of the main problems or challenges of smart specialisation approaches and regional innovation systems is the problem of politico-economic structural barriers of governance linkages of the national and regional Innovations Systems. In India, there is a classic division between the state government and the central government. In most of the policies which the central government starts there is a mechanism for joint financing of the programs and schemes and in most of the cases there is a problem of funds for investment and expenditure by the states. This is also reflected by the fact that the state's share in GERD is very low and they face problems in supporting the eco-system of research and innovation. The problems and lack of expenditure in research and development and innovation in the states in terms of share of GERD shows that states are contributing much less (7.2%) compared with the central government share in GERD which stands at 57.4% for the regional innovation systems.[64]

India closely tracks the new STI developments in EU, USA, China and Japan. Consequently, Indian ministry of science and technology is quite aware of EU's smart specialization policy approach.

There are various smart specialization programmes (for instance digital India, National Knowledge Network, Techpedia and Grassroot Innovations) which are attempting to

62 http://www.dst.gov.in/st-system-india/science-and-technology-policy-2013

63 http://www.nstmis-dst.org/

64 http://digitalrepository-nstmis-dst.org/files/stats/2011-12/Full_Text_2011-12.pdf

reach and network across multi lingual, multi-regional and multi ethnic sections of India. Techpedia, an initiative at Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI) in collaboration with National Innovation Foundation, DST and Honey Bee Network Grassroots innovations data bank of ideas provide some lessons (See 4.2).

5. Internationalisation of R&I

5.1 India in the global R&D system

The emergent aspects of Indian economy in terms of economic prospective and global rise as one among the upcoming hot-spots for global R&D and R&D market reflects the emerging importance of India in global R&D landscape. The overall R&D expenditure doubled since 2007, which stands at US40 billion in 2012 and then to US $ 44 billion in 2014. India's R&D expenditure is 2.7% of the global R&D expenditure compared to USA 33.6%; and Japan and China accounting for about 12.6% each in 2012.[65]

In the last decade India has been a major destination of Foreign Direct Investment in R&D and an attractive knowledge based location for Transnational Corporations such as Microsoft, General Electric among others. In 2015, over 1070 multinational firms have established R&D centers or laboratories in various cities of India. Between 2000 and 2013 establishment of these foreign R&D centres increased at an annual rate of 13.8% giving employment to 244 000 professionals.[66] These R&D centres or R&D-based firms mainly operate in ICT, biotechnology, pharmaceuticals, telecommunications and automobiles. During the last decade, Bangalore, Pune, Chennai, Calcutta, NCR Delhi and Hyderabad's high technology city are among the major destinations for foreign R&D centres. These cities have emerged as global R&D and innovation hubs or networks with horizontal and vertical integration to globally dispersed TNCs.

According to a survey of 649 firms about 239 (37%) firms have their R&D units in Bangalore. Hyderabad is in second position, which accounts for 14.79% of the firms, followed by Delhi the National Capital Region with 10.47% of the total units. Big Indian software firms such as Tata Consultancy Services, Infosys, Mahindra Satyam Computers, Hindustan Computers, among others have become important actors in the globally dispersed networked innovation processes in a number of high technology areas such as aerospace, automotive, telecommunications, banking and finance etc. In varying ways, Indian developments reveal the changing structure of TNCs in the context of 'new approach', which moves towards globalized programmes for innovation and R&D.

Given the growing middle classes, who will account for more than half billion people by 2020 and demographic dividend of young population, India offers a huge global market. India already emerged as the global source for highly skilled human resources. The economy of scale in high technology manufacturing is likely to become the main global attraction for R&D and commercialization of innovation from India in the coming decade.

[65] See Battelle India and FICCI Report on, India's Emerging Competitiveness as Destination of Global R&D, 2013.

[66] See www.ibef.org

5.2 Main features of international cooperation policy

The overall purpose and approach of India's International S&T Cooperation Policy [67] [68]

India both in terms of population and economic size is among the top five in the world. It seeks to play an important role in global sustainability, peace and development in the world. These are some crucial factors which drives India's international cooperation in the global science and technology system. Other important features are as follows:

- To build and encourage partnerships based on mutual interaction which caters to enhancement of knowledge and learning.
- To nurture relationship in international cooperation not only limited to government to government relationship but to also incorporate academia and private sector.
- To have collaborative mechanisms for research and development such as joint projects, joint research centres working for societal challenges both at national and international level.
- Furthermore, the above also co-relates to the objective and approach of having academic collaboration in terms of workshops, seminars and meetings pertaining to national and international concerns in science, technology and innovation.
- To encourage scientific human resource exchange, information and knowledge dissemination through bi-lateral, multi-lateral and regional mechanisms.
- To track and learn best practices, policy measures and exemplars in STI models found in various countries.

Cooperation framed in agreements and instruments/mechanisms could be categorised and understood fewer than four groups:[69]

First, contacts building through different academic collaborations such as joint workshops/ seminars/symposiums/exhibitions, fellowships & internships, exploratory visits, lectures by eminent scientists and sending young research scholars to international events to meet and interact with peers with other countries.

Second, providing support for collaborative research & development projects of mutual interest, project based exchange, human resource training, access to better and advanced science research infrastructure facilities and also to participate in 'big science' projects.

Third, to facilitate and promote collaborative clusters of R&D, networked centres build on virtual platforms, multi-institutional projects on R&D and also creation of joint ventures.

Fourth, encouragement and support for commercialisation of research and development and innovation. Under this area the larger aspects of triple-helix type of relationship are encouraged, public-private partnership for innovation and entrepreneurship, support the process of technology development & transfer and to have annual technology meets with collaborative partner country.

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67 http://www.dst.gov.in/international-st-cooperation

68 http://www.dst.gov.in/st-system-india/science-and-technology-policy-2013

69 http://www.dst.gov.in/international-st-cooperation

So the above mentioned India's international S&T cooperation objectives, approaches and instruments of cooperation operates at different institutional levels which are bilateral, multilateral and regional cooperation mechanism. This is mainly executed with help of meetings of head of states during official state visits, ministry and department level meetings and special meetings on science, technology and innovation in the domain of business and trade. However, there is also a domain of cooperation in which there is cooperation through contact and collaboration of international organisations and charity foundations which support and invest in research & development and innovation for addressing societal challenges pertinent around the world.[70]

The main areas for India's collaboration with different countries could be understood with the following table:

Table 9 : India's S&T Collaboration with Select Countries (2011-2015)[71]

S&T Disciplines										
Country	Maths	Physics	Chemistry	Biology	Medicine & Health	Environment & Energy	Geography	Engineering	Technology	Country Wise Total Projects.
USA	-	6	5	5	57	12	1	8	10	104
Canada	-	-	-	2	48	7	-	3	5	65
Japan	2	12	14	23	12	2	4	8	9	86
China	-	-	-	-	-	-	-	-	-	-
France	5	18	10	14	9	2	6	3	5	72
Germany	3	16	15	9	3	-	3	10	11	70
Total	10	52	44	53	129	23	14	32	40	397

The above table shows India's international S&T cooperation with some select countries from 2011-15. The collaboration in terms of different projects encompasses different discipline of enquiry like fundamental sciences which includes maths, physics, chemistry, biology, areas of medicine & health, environment & energy, geography, engineering and technology. Some of the indicators from the above table points towards some facts such as India have a large number of collaboration in the field of medicine and health having 129 projects in total. This reflects one of the major societal concerns in India related to public health and wellbeing. India having a huge population of 1.2 billion people also makes it a country which is vulnerable with health and medicinal challenges. This crucial factor pushes the inclination of more collaboration in this field. But if we combine the fundamental and pure sciences which would incorporate maths, physics, chemistry and biology then the total share of projects would be 159 projects which in a grouped manner surpass the total number of projects of medicine and health, but individually medicine and health remains the largest. India and Indian scientists in pure and

70 https://rio.jrc.ec.europa.eu/en/file/9033/download?token=8Hof1LRH

71 V.V. Krishna (with the assistance of Rajiv Mishra) *Gap Analysis between EU-India and Other Countries: Indian Perspective,* Centre for Studies in Science Policy - Jawaharlal Nehru University New Delhi, Report Commissioned by Centre for Social Innovation, in the framework of Indigo Policy (FP7) Vienna, 2015.

fundamental sciences have a global reputation. India has achieved global recognition in the field of maths, astronomy, physics and nuclear science and space research.

5.2.1 National participation in intergovernmental organisations and schemes and multilateral agreements

Some of the important forums in which India participates with respect to multi-lateral, bilateral and regional in science and technology cooperation are European Union, ASEAN, UNESCO, BRICS and UNDP in the multilateral domain. In the bilateral domain India has cooperation with 83 countries in which some major cooperation platforms which have resulted from the bilateral relationship are Indo-US Science & Technology Forum (IUSSTF), Indo-German Science & Technology Centre, United States India Education Foundation (USIEF), Castro Indo – Canadian Institute and Indo – Russian Institute. In the regional domain of cooperation some of the forums are BIMSTEC, Indian Ocean Rim, ASEAN and SAARC. Lastly, outside the domain of the government some better foundations such as Bill & Melinda Gates Foundation, Ford Foundation and Rockefeller Foundation. India entered into 300 multilateral cooperation projects between 2011 and 2015 with 59 each with USA and Canada; 2 each with Japan and France; 3 with Germany; and 175 with EU.[72]

India's cooperation in big science and high technology projects with EU are as follows:[73]

a) India is a member of the European Union's International Thermonuclear Experimental Reactor (ITER) nuclear fusion energy project. ITER is an international Tokamak research and engineering project designed to prove the scientific and technological feasibility of a full-scale fusion power reactor. It is an experimental step between today's studies of plasma physics and future electricity-producing fusion power plants.

India joined the satellite based navigation system, Galileo Project (European version of USA's Global Positioning System). Recently in 2014 there was also a meeting between EGNSS (European Global Navigation Satellite Systems) and Indian GAGAN (GPS and Geo-Augmented Navigation System) project members for making EGNOS (European Geostationary Navigation Overlay Service) and GAGAN project related to satellite based navigation compatible with each other. Both EGNOS and GAGAN are satellite based navigation and augmentation System. Furthermore, India's National Knowledge Network is linked up to

a) European equivalent of GEANT and is also part of the Trans-Eurasia Information Network (TEIN).
b) India and the European Union have decided to embark on 'big science' projects. India signed a pact with the EU to participate in the proposed Facility-for-Antiproton-and-Ion-Research (FAIR) project aimed at understanding the tiniest particles in the universe. Indian participation in this project has been in the front of experiments and accelerators components, where Indian scientists are drawing there past expertise in this area in collaboration with European scientists. More specifically Indian scientists are studying and understanding Antiproton and Ion Research and would be building detectors like NUSTAR (Nuclear Structure, Astrophysics and Reactions), Compressed Baryonic Matter (CBM) and Anti-proton Annihilation at Darmstadt (PANDA).

c) India is partner for the major EU's international project – European Organization for Nuclear Research, CERN, contributing to the Large Hadron Collider.

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72 V.V. Krishna (with the assistance of Rajiv Mishra) *India S&T Cooperation with EU and Other Select Countries*, Centre for Studies in Science Policy - Jawaharlal Nehru University New Delhi, Report Commissioned by Centre for Social Innovation, in the framework of Indigo Policy (FP7) Vienna, 2015
73 Ibid.

5.2.2 Bi and multilateral agreements with EU countries

India and EU have good trading relationship which is reflected in the total figures of € 69 billion Euros trade in different goods and services in the year 2009. European Union's share in India's total exports stands at 21% and India takes the share of 2.5% in total exports of EU. EU has been investing heavily from the recent past decade which is reflected in the figures of € 20.0 billion investments since 2000.[74] Furthermore, the better tie in trade and business between India and EU is also extended in the sphere of science and technology cooperation between them. India and EU have been cooperating in the domain of science and technology with help of different cooperation framework programs started by European Union. Table below shows the number of science and technology collaboration projects between India and European in the time span of past 19 years. Starting with framework cooperation called *FP4 (Framework Program 4)* and then further going into *FP5, FP6* and *FP7,* India and European Union have grown and developed in their science and technology cooperation. The latest FP7 program which ended in 2013 had 175 science and technology projects which were more than 6 times the total number of projects during 1994-1998. Even going by the total number of 300 projects collaborated between India and EU under the ambient of all EU framework programs the latest FP7 program contribution stands at 58%. This also reflects that India and EU have shown tremendous scope and desire to work together in the domain of science, technology and innovation.

Table 10: India-EU Collaboration in FP4, FP5, FP6, FP7 programs from (1994-2013)[75]

Framework Programs	Total Projects
FP4 *	33
FP5 *	32
FP6 *	60
FP7 *	175
All Total	300

* FP4 (1994-1998), FP5 (1998-2002), FP6 (2002-2006) FP7 (2007-2013)

Participation in EU Framework Programmes[76]

Some of the major areas of cooperation which have largely defined the nature of international cooperation between India and EU are related to Environment and Climate Change, Energy with specific interests in clean and renewable energy, materials science, public health and nutrition and water management technologies. Furthermore, recently in 2012 a Joint Declaration on Research and Innovation Cooperation between India and European Union was issued. This was seen as an outcome of necessary ground created by the experiences gained from framework cooperation programs between India and EU. Upton this time the amount of funding which was jointly provided by India and EU was 60 million Euros, but in 2012 the financial support was taken into new high after EU promised 8.1 billion Euros. The favourable condition which India received in EU framework cooperation investment bidding was also related to the fact that India stood at par with any other European Union country and North America in the process of bidding for the projects investments. Furthermore, as mentioned earlier that India and EU have moved ahead in the domain of science and technology cooperation which is also

74 http://erawatch.jrc.ec.europa.eu/erawatch/export/sites/default/galleries/generic_files/file_0347.pdf

75 V.V. Krishna (with the assistance of Rajiv Mishra) *India S&T Cooperation with EU and Other Select Countries*, Centre for Studies in Science Policy - Jawaharlal Nehru University New Delhi, Report Commissioned by Centre for Social Innovation, in the framework of Indigo Policy (FP7) Vienna, 2015

76 V.V. Krishna (with the assistance of Rajiv Mishra) *India S&T Cooperation with EU and Other Select Countries*, Centre for Studies in Science Policy - Jawaharlal Nehru University New Delhi, Report Commissioned by Centre for Social Innovation, in the framework of Indigo Policy (FP7) Vienna, 2015

evident from the fact that India was the 4th ranked international cooperation partner with EU in terms of scale of cooperation in EU FP7 program in the time phase of 2007-13.

Programmes of Participation[77 78]

International cooperation between India and EU in the domain of science, technology and innovation within the ambit of EU framework programs incorporate wider gamut of enquiry like fundamental sciences which includes physics and space, information and communication technologies and upcoming technologies like nanotechnology.

- The financial support for international science and technology cooperation from the department of science and technology in the period of 2012-15 was € 52.18 Million out of which a better proportion was for EU framework cooperation programs.

- EU and India agreed upon to collaborate and participate in the proposed Facility-for-Antiproton-and-Ion-Research (FAIR) project which fundamentally tries to understand the most fundamental particles in the universe.[79]

- India and EU have entered into a crucial partnership for collaboration in the field of nuclear technology.

- Furthermore, apart from the field of nuclear technology under the domain of energy, India and EU have also agreed *Joint Work Programme on* energy, clean development and climate change. A collaborative call for Solar Energy Research was launched in 2009 with €5 million contributions from each side. The programme continued till 2012.[80]

- India and EU are also collaborating in the satellite based navigation system, Galileo Project of which India became a partner and it is an active participant in FP7. [81]

- India and European Union cooperation in the domain of ICTs named *Euro-India* is a crucial project in the area of Information Technology which through use of ICTs tries to mark and carry forward European Union and Indian Research & Technology Development (RTD) capacity. The crucial goal includes marking of information and communication technologies research & innovation activities throughout India and listing the Indian ICT research & development players supported by information days and technology brainstorming sessions throughout India. India also participated in the FP 7 ICT programmes.[82]

- European Union and India have also agreed upon cooperation in the field of nanotechnology. The funds committed for this project was 5 million Euros by both the sides, project was commenced in 2008 and was carried till 2011.

- India and European Union have also agreed to spend 5 million Euros every year in joint research. Both the side have also agreed to have coordinated calls for proposals which up to 2013 there were 5 co-ordinated calls[83].

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77 http://erawatch.jrc.ec.europa.eu/erawatch/export/sites/default/galleries/generic_files/file_0347.pdf

78 V.V. Krishna (with the assistance of Rajiv Mishra) *India S&T Cooperation with EU and Other Select Countries*, Centre for Studies in Science Policy - Jawaharlal Nehru University New Delhi, Report Commissioned by Centre for Social Innovation, in the framework of Indigo Policy (FP7) Vienna, 2015

79 http://www.fair-center.eu/

80 http://www.access4.eu/india/525.php

81 http://eeas.europa.eu/delegations/india/documents/catalogue.pdf

82 Ibid.

83 http://ec.europa.eu/euraxess/index.cfm/links/collaboration_opportunities/india

- There was limited number of co-ordinated calls in FP7 framework program with small number of partner countries which also involved organisations from third world countries.[84] The five coordinated calls were related to the following areas:
    - Computational Materials Science (2007)
    - Food and Nutrition Research (2008)
    - Solar Energy Systems (2009)
    - Partnering Initiative on Biomass and Bio wastes (2010)
    - Water Research (2011)

- A project related to networking and research co-operation between researchers in India and four European countries in clearly defined areas has been launched by the Netherlands Organisation for Scientific Research (NWO), the French Agence National de la Recherche (ANR), the Deutsche Forschungsgemeinschaft (DFG), the British Economic and Social Research Council (ESRC) and the Indian Council of Social Science Research (ICSSR).
- European Union and India have jointly proposed a new collaborative projects funding policy mechanism called The New INDIGO funding Programme which is formally known as New INDIGO Partnership Programme having supporting mechanism for Indo-European multilateral research and networking projects. As per year 2013 there have been four joint collaborative calls which included 60 research scientists across ten countries. Some of the areas related to the calls were on health & bio-technology and water.[85]
- Another important area of research cooperation between India and European Union in relation to exchange of scientific human resource is the *'Marie Curie Actions'.* This programme which was initially based on mobility measures for research fellows has now been completely oriented and approached towards scientists' career growth. Under this program there is a scheme called *Marie Curie International Research Staff Exchange Scheme* which is an approach to further make the research cooperation stronger with help of exchanges and mutual learning based on wider networking with EU and partner country. Under this program in the time phase of 2007-13, 833 Indian research scientists spanning from 78 different organisations around India have participated with total funding support of 4.5 million Euros.[86]

Bi- and multilateral agreements with EU countries

India has bilateral and multilateral cooperation agreements with EU countries outside the domain of European Union framework cooperation. Some of the better known EU countries having established formal science and technology cooperation platform are France, Germany, England and Belgium. India and France have established a joint research platform called Indo-French Centre for the Promotion of Advanced Research (CEFIPRA). India and France in the time phase of 2011-2015 had 72 bilateral projects and 2 multilateral projects.[87] Some of the prominent areas of cooperation between India and France include physics, chemistry, biology, medicine and health. They have also signed a space cooperation mechanism comprising ISRO (Indian Space Research Organisation) and CNES (France) to study earth sciences and climate change. There is also a bi-lateral agreement signed in 2012 for cooperation in the domain of life sciences, bio-technology, Nano-technologies, ICTs and Innovation. Furthermore, both the countries have agreed to joint partnership mechanisms for advanced research through

84 Ibid.

85 https://indigoprojects.eu/

86 http://eeas.europa.eu/delegations/india/documents/catalogue.pdf

87 V.V. Krishna (with the assistance of Rajiv Mishra) *India S&T Cooperation with EU and Other Select Countries*, Centre foro Studies in Science Policy - Jawaharlal Nehru University New Delhi, Report Commissioned by Centre for Social Innovation, in the framework of Indigo Policy (FP7) Vienna, 2015

joint laboratories related to chemistry, physics and nuclear sciences, water and medical research. India and Germany have jointly established a body called Indo-German Science and Technology Centre (IGSTC) and had 70 bilateral science and technology cooperation projects and 3 multilateral cooperation projects. Some of the major areas of cooperation between India and Germany are fundamental and pure sciences related to physics, chemistry, biology and areas of engineering and technology with emphasis on power and instrumentations.[88]

India and UK for international cooperation in science and technology have a platform called *Indo-UK Science and Innovation Council*. This council is a collaborative mechanism for promotion of science and technology and its societal linkages with emphasis on people, research and translation. Some of the domains of cooperation under this council are related to manufacturing, sustainable development, public health its relation to nutrition and water, environment & energy and big data analytics. India and UK have cooperation in the field of biomedical science, climate change, joint defence R&D and health. India and UK have agreed to have a collaborative defence R&D. Furthermore, India and Belgium have also signed a research & development and innovation cooperation mechanism in 2011 in the areas of nanotechnologies, renewable energy, bio-pharmacy and aviation.[89]

The pattern of cooperation with EU under the framework cooperation programme and cooperation with EU countries outside the cooperation has some interesting patterns to be reflected upon. Firstly, the international science and technology cooperation between India and European Union has been under the ambit of a special mechanism called *Framework Programme.* One of the interesting aspects is that this framework programme is set by the governing mechanism of EU for international science and technology cooperation. This has its own unique funding mechanisms, its set goals and defined objectives. But having an overall framework programme for most of the countries which brings problems of context based issues such Indian scenario of science and technology has its own contextual dynamics, the links in terms of government-industry and academia is not yet strong and the nature of cooperation in this program is very much based on asymmetrical participation ratios of institutions from EU and India.[90] Sometimes there is a large number of EU partner institutions and only few Indian institutions which brings its own complexities. Even though India and EU have grown and developed in their science and technology cooperation from past till now but since there is no dedicated cooperation institutional body like the case of IFCPAR for India-France, IGSTC for Indo-German, IUSSTF for Indo-US etc most of the co-ordination work is done by co-ordinators who are based in European organisations. The lack of a dedicated platform also brings problems of institutionalisation, legal and IPRs support and commercialisation and innovation of collaborative scientific research.

Furthermore, France and Germany are two prominent partners of India in EU outside the domain of European Union framework cooperation program. France has established a credible and grounded relationship with India with help of a major science and technology cooperation platform called CEFIPRA/IFCPAR. This institute has worked in a catalytic manner which has promoted science and technology cooperation between the countries in newer heights. It gets financial support from department of science and technology, government of India and ministry of foreign affairs, government of France. Secondly, the Indo-German Science and Technology Centre (IGSTC) has been also one of the prominent examples related to science and technology cooperation India and an

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88 Ibid.

89 V.V. Krishna (with the assistance of Rajiv Mishra) *India S&T Cooperation with EU and Other Select Countries*, Centre for Studies in Science Policy - Jawaharlal Nehru University New Delhi, Report Commissioned by Centre for Social Innovation, in the framework of Indigo Policy (FP7) Vienna, 2015

90 V.V. Krishna (with the assistance of Rajiv Mishra) *Gap Analysis between EU-India and Other Countries: Indian Perspective,* Centre for Studies in Science Policy - Jawaharlal Nehru University New Delhi, Report Commissioned by Centre for Social Innovation, in the framework of Indigo Policy (FP7) Vienna, 2015

EU country outside the domain of EU cooperation framework. It is working to effectively use the partnership of government, academia and industry partnership.

The cooperation framework between India and EU as mentioned and shown in Table, shows the growth and development of cooperation framework both in time and scale. Seeing the data from 1994-2013 of four cooperation framework programme of FP4, FP5, FP6 and FP7. European Union's science & technology cooperation with India has been enhanced and developed in the time period of 2002-2013. This time period show the execution of two framework programs of FP6 (2002-06) and FP7 (2007-13) which has taken the cooperation between the two sides into new heights.[91] The FP6 programme was the cooperation framework program which reflected the glimpses of strong future science & technology cooperation between India and European Union. FP6 had total of 60 projects and brought 100 science & technology based institutions from Indian into cooperation. The amount of financial support provided for FP6 programme with respect to India was 11 million Euros. However, the EU framework program of FP7 has been a major cooperation framework program which brought a total of 41 million Euros in financial support, 175 science & technology projects and show participation of 300 institutions in collaborative scientific research.[92] [93]

Furthermore, with the end of FP7 program in 2013 a new international cooperation mechanism between European Union and India was launched called INNO INDIGO which was the replacement for NEW INDIGO policy of 2013.[94] This INNO INDIGO policy has been launched for the time period 2014-2016 and is currently functional. However, one important change with respect to past EU framework cooperation framework programs and INNO INDIGO policy is the mechanisms for funding. In the current INNO INDIGO policy both the Indian and EU collaborating partners have to try to rope their own sources and resources for funds support. The current policy programme of EU related to Research & Innovation called *Horizon 2020* is for the time phase of 2014-2020 and provides provisions for science & technology related human resource exchange and also involvement in European Research Councils grants.[95]

Coming back to one of the most important latest cooperation framework program of FP7 which ended in 2013 shows us some interesting patterns and facts. We can see that the total number of projects during Out of these cooperation frameworks the latest *FP7* program, which has been in the time phase of 2007-2013 has been very crucial for India – European science and technology cooperation.

Table 11: India's Participation in FP 7 Projects (2007-2012)[96]

Proposal SP Description	Program Proposal	Number of Proposals Submitted	Number of Applicants	Number of Proposals Main listed	Number of Applicants	Proposal Total Cost	Success Rate: applicants in Main listed proposal / applicants in all.
Not Available	N/A	2	2				

91 http://www.newindigo.eu/programme/eu_framework.html
92 http://eeas.europa.eu/delegations/india/documents/catalogue.pdf
93 http://www.newindigo.eu/programme/eu_framework.html
94 https://indigoprojects.eu/
95 http://eeas.europa.eu/delegations/india/documents/h2020_brochure-india-aug_2014.pdf
96 V.V. Krishna (with the assistance of Rajiv Mishra) *India S&T Cooperation with EU and Other Select Countries*, Centre for Studies in Science Policy - Jawaharlal Nehru University New Delhi, Report Commissioned by Centre for Social Innovation, in the framework of Indigo Policy (FP7) Vienna, 2015

SP1-Cooperation	ENERGY	49	99	7	10	39,786,738	10.10%
SP1-Cooperation	ENV	111	217	18	36	85,726,601	16.59%
SP1-Cooperation	GA	2	8				
SP1-Cooperation	HEALTH	145	236	33	57	162,202,205	24.15%
SP1-Cooperation	ICT	157	225	19	29	93,147,129	12.89%
SP1-Cooperation	KBBE	102	156	19	32	79,129,986	20.51%
SP1-Cooperation	NMP	31	56	7	13	47,876,841	23.21%
SP1-Cooperation	SEC	7	8	2	2	10,052,737	25.00%
SP1-Cooperation	SPA	14	16	3	3	8,572,954	18.75%
SP1-Cooperation	SSH	134	189	9	14	37,484,301	7.41%
SP1-Cooperation	TPT	33	46	10	14	32,907,462	30.43%
SP2-Ideas	ERC	14	15				
SP3-People	PEOPLE	298	340	70	92		27.06%
SP4-Capacities	INCO	20	44	7	18	11,637,095	40.91%
SP4-Capacities	INFRA	20	53	7	20	18,571,818	37.74%
SP4-Capacities	REGIONS	3	3				
SP4-Capacities	SiS	26	29	10	11	16,952,756	37.93%
SP4-Capacities	SME	9	9				
SP5-Euratom	Fission	2	2				
	Sum:	1,179	1,753	221	351	644,048,623	20.02%

The above table related to FP7 projects shows Indian requests in terms of proposals for different cooperation programs in FP7 framework program. From the table we can find out that some of the areas of cooperation in which highest amount of proposals in the time phase of 2007-2012 were environment, health, ICTs and people centric science and technology cooperation projects. Furthermore, going by the figures of total number of proposals submitted, number of applicants, number of proposals main listed, funding and success rate of proposal acceptance we find that 1,179 proposals were submitted out which 221 were main listed with acceptance percent ratio of 20%. This reflects the fact that a good amount of Indian research scientists showed intention and desire to participate in EU framework programme, evident from the fact that total number of applicants stood at 1,753.

Table 12: Indian contract type of the FP 7 projects with the country's participation[97]

Proposal Sub Funding Description	Number of Proposals	Number of Proposals
Collaborative project for specific cooperation actions dedicated to international cooperation partner countries (SICA) [i]	211	39
Collaborative project (generic) [ii]	68	13
Collaborative Project targeted to a special group (such as SMEs) [iii]	23	3
Coordinating action [iv]	91	24
Industry-Academia Partnerships and Pathways (IAPP) [v]	3	1
Initial Training Networks (ITN) [vi]	20	5
Integrating Activities / e-Infrastructures [vii]	7	1
International Incoming Fellowships (IIF) [viii]	165	12
International Outgoing Fellowships (IOF) [ix]	14	3
International Research Staff Exchange Scheme (IRSES) [x]	93	49
Large-scale integrating project [xi]	94	15
Network of Excellence [xii]	2	2
Small or medium-scale focused research project [xiii]	184	23
Small or medium-scale focused research project INFSO (STREP) [xiv]	69	1
Supporting action [xv]	99	30
Sum:	1,179	221

97 V.V. Krishna (with the assistance of Rajiv Mishra) *India S&T Cooperation with EU and Other Select Countries*, Centre for Studies in Science Policy - Jawaharlal Nehru University New Delhi, Report Commissioned by Centre for Social Innovation, in the framework of Indigo Policy (FP7) Vienna, 2015

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i) SICA: A EU S&T Cooperation specifically targeted for a region or a country.
ii) Research done with a consortium of academia and industry partners.
iii) Research collaboration for strengthening the innovation capacity of SMEs in partner countries.
iv) Projects which not only incorporates research, but also coordinating and networking of projects.
v) Incorporates research collaboration between industry and academia.
vi) Provides early career stage researchers an opportunity to join good research institution.
vii) Facilities, resources and services used by the research communities for research.
viii) Experienced researchers offered support to undertake research projects in Europe
ix) At post-doctoral level allow European researchers to pursue their work in India
x) Inter-organisations coordinated exchange programme to strengthen cooperation.
xi) Research and technology development, demonstration and management activities.
xii) For research institutions adding and integrating activities and capacities to create a European virtual research centre.
xiii) Promoting research collaboration & participation involving small and medium scale actors.
xiv) A research collaboration having objective focused approach and having clear mandated work plan
xv) Support for cooperation with other European research schemes

The table above shows details of funding and contracts in terms of number of proposals submitted and clearly reflects the specific areas of funding cooperation mechanism in the FP7 programme which had more number of proposal submissions. Three important areas of proposal areas for funding are collaborative projects for specific cooperation actions dedicated to international cooperation partner countries called SICA which had 211 proposal submissions, second high has been the category of International Incoming Fellowships (IIF) got 165 proposals and third largest was the small and medium scaled research project which got a total of 184 proposals.

Table 13: Classification of Projects in FP7 Program (2007-2013).* [98]

	General Thematic Classification of Number of Science & Technology Projects in FP7 Program (2007-2013).*										
Programs	Health & Medicine	Food/Agriculture/Biotechnology	ICTs	Nano technology/ Materials	Energy	Environment	Transport	Space	Marie Curie** Exchange	Nuclear	Total
FP7	38	21	19	13	10	24	8	3	37	2	175

* This thematic classification is as per categorisation in FP7 projects catalogue and this also excludes projects related to social sciences and humanities.
**Marie Curie Actions Research Staff Exchange

The above table shows the general thematic classification of projects in FP7 programs which clearly shows that three most important areas of science and technology cooperation between India and EU has come up and which would necessarily define the future landscape of India and EU S&T cooperation. These areas of cooperation are health and medicine, food and nutrition, environment, energy, environment and exchange projects. From the above table we see the figures that S&T projects related to health and medicine has been highest in the FP7 program having highest share of 38 projects in the total of 175 projects. The second highest project cooperation was the scientific

98 V.V. Krishna (with the assistance of Rajiv Mishra) *India S&T Cooperation with EU and Other Select Countries*, Centre for Studies in Science Policy - Jawaharlal Nehru University New Delhi, Report Commissioned by Centre for Social Innovation, in the framework of Indigo Policy (FP7) Vienna, 2015

personnel exchange program which had 37 projects and which was followed by food & agriculture having 21 projects, environment 24 projects and energy 10 projects.

India and European Union have both grown together in their science & technology cooperation. As discussed above that the relationship of collaboration started from FP4 framework program in 1994 which was taken forward enthusiastically until the latest FP7 cooperation framework program. As discussed above and also to see that, the tables pertaining to the domains of cooperation between India and EU in FP7 collaboration incorporated wider sub-disciplines of science & technology. In the table which shows that 'India's Participation in FP7 programs' shows glimpses of interest and intent of Indian researchers for participation actively in certain areas of cooperation. Areas like energy, environment, ICTs, health, water and people related projects proposals. Furthermore, the specific information provided in the table related to classification of projects in FP7 program we find a clear indication of emerging patterns of scientific collaboration between India and EU. The pattern shows that the some of the more collaborated areas were health & medicine, food, environment and energy as on 2013 when the latest FP7 program. One another area which also relates to emerging trend of cooperation and which was also reflected in the FP7 framework program was the Marie Curie Exchange Program.

Furthermore, some assessment studies related to science & technology cooperation between India and European Union co-relate with the above pattern of collaboration with some specificities. With respect to INDIGO Policy which is supporting project related to and under FP7 framework cooperation further co-relates the above emerging trends. Some of the emerging areas which have been highlighted in INDIGO policy are related to health, water and energy. Taking two important indicators of co-publishing and co-patenting related to international science & technology cooperation between India and EU, these trends have been statistically validated. In the domain of health research cooperation, two important areas related to it were diabetes research and affordable health. ERA (European Research Areas) countries had collaboration in terms of 38% share in Indian international co-publication related to diabetes research in the time phase of 2002-2012.[99] In the area of affordable health research, India and ERA countries had a share of half the amount of international publication. In the domain of water, India and ERA countries had 37% co-publication related to drinking water, 41% on waste water and 46% on urban water management.[100] In terms of co-patents the PATSTAT (EPO Worldwide Statistical Patent Database) statistics shows that more than 1750 patent applications as second fillings were applied in European Patent Office (EPO) after first fillings in Indian Patent Office.[101]

However, these patterns have been put into new perspective and vigour with the latest Horizon 2020 program of cooperation between India and European Union for the years 2014-2020. The Horizon 2020 program which has an estimated 80 billion Euro funding, has prioritized three important domains of scientific cooperation, first, cooperation under the domain called excellent science, in which areas liking funding for frontier research, Marie curie actions for scientists & researchers exchanges, future & emerging technologies (FETs) and cooperation in research infrastructure have been prioritized with allocation of 24.4 billion Euros.[102] Second, is the priority area called industrial leadership which incorporates two sub-areas called 'leadership in enabling and industrial technologies' which gives importance to strategic cooperation in the areas of advanced manufacturing & materials, biotechnology, Nanotechnologies, ICTs and space with a

99 Kaisa Granqvist and Katharina Busel, *Policy-Brief: Co-Publishing Patterns of EU-India:*The International Dimension of co-publishing in India with special regard to European Union. INDIGO Policy, Centre for Social Innovation GmbH (ZSI), Wien, Austria, 2015.

100 Ibid.

101 Florian Gruber and Florina Piroi, *Policy-Brief: Co-Patenting in India:*The International Dimension of co-patenting in India with special regard to European Union. INDIGO Policy, Centre for Social Innovation GmbH (ZSI), Wien, Austria, 2015.

102 http://eeas.europa.eu/delegations/india/documents/h2020_brochure-india-aug_2014.pdf

total budget outlay of 17 billion Euros.[103] Third, being science & technologies cooperation for addressing certain societal challenges like environment, sustainable development, health, energy, food, clean technologies and inclusive innovations with outlay of 27.9 billion Euros.[104]

103 https://eeas.europa.eu/delegations/india/documents/h2020_brochure-india-aug_2014.pdf
104 Ibid.

Table 14: Mapping of some best Indian and EU institutions under FP7 program in different thematic areas of collaboration.[105]

Different thematic areas under FP7	Indian Institutions	EU Institutions
Health & Medicine	Madras Diabetes Research Foundation, Chennai	London School of Hygiene & Tropical Medicine, UK
	All India Institute of Health Science and Research, New Delhi	University College London, UK
	Christian Medical College, Vellore	Karolinska Institute, Stockholm, Sweden
	Public Health Foundation of India, Delhi	Institute of Tropical Medicine Antwerp, Belgium
	St. John Medical College and Hospital, Bangalore	University of Helsinki, Finland
Energy	Indian Institute of Technology, Delhi	Hahn-Meitner Institute Berlin, Germany
	Indian Institute of Technology, Mumbai	Ecole Polytechnique, Paris
	Indian Institute of Science, Bangalore	Karlsruhe Institute of Technology, Germany
	Tata Institute of Fundamental Research, Mumbai	University de Nantes, France
	National Institute for Interdisciplinary Science and Technology, Thiruvananthapuram	University of Manchester, UK
Water	Jawaharlal Nehru University, Delhi	University of Applied Sciences Dresden, Germany
	Indian Institute of Technology, Roorkee	University of Basel, CH
	TERI University, Delhi	London School of Hygiene & Tropical Medicine, UK
	Jadavpur University, Kolkata	Wessex Institute of Technology, UK

105 Table Compiled from various sources of India and EU cooperation on FP7 program.

ICTS	Indian Institute of Technology, Mumbai	Technical Support for European Organisations SPRL, Belgium
	IBM India Pvt. Ltd	ADVA AG Optical Networking, Germany
	Centre for Development of Advanced Computing, Pune	Sap AG, Germany
	Software Technologies Park of India, India	European Telecommunications Standards Institute, France
Manufacturing & Materials	Jawaharlal Nehru Centre for Advanced Scientific Research, India	Institute of Nano Technologies, UK
	Bhabha Atomic Research Station, India	Federal Institute for Materials Research and Testing, Germany
	National Chemical Laboratory, India	Valtion teknillinen tutkimuskeskus, Finland
Food & Agriculture	Tamil Nadu Agricultural University, India	Advanced Biological Technologies Belgium, Belgium
	Punjab Agricultural University, India	Swedish University of Agricultural Sciences, Sweden
	International Crops Research Institute for Semi Arid Tropics, India	Centre international en recherche agronomique pour le développement, France
Environment & Climate Change	The Energy and Resources Institute, India	Wageningen University, Netherlands
	National Institute of Hydrology, India	Laboratoire des Sciences de l ’Image, de l ’Informatique et de la Télédétection, ULP, France
	GB Pant Institute of Himalayan Environment & Development, India	IUCN - The World Conservation Union, Switzerland

Marie Curie Actions	Tata Institute of Fundamental Research, India	Centro de Investigacao em Astronomia e Astrofisica da Universidade do Porto, Portugal
	Indian Statistical Institute, India	Consorzio COMETA, Italy
	Indian Institute of Technology Kanpur, India	Imperial College of Science, Technology and Medicine, United Kingdom

The above table maps the best institutions of India and EU in relation to the past collaboration of FP7 framework program and their potential scope in future collaborations as prospective future research partners in certain thematic areas of cooperation. From the above table we find that some of the key thematic areas of cooperation which has emerged from FP7 cooperation and is being emphasized in the current *Horizon 2020* include, *health & medicine*, *energy*, *water, ICTs, manufacturing & materials, environment & climate change* and *Marie Curie actions* for scientific exchanges.[106] The above listed institutions both from India and European Union have been prioritized in the thematic area of cooperation in FP7 program.

5.3 Assessment of options for JRC collaborations

The JRC has been collaborating with various Indian institutions over the years. EU's Horizon 2020 and New INDIGO are also coordinated and linked to the activities of JRC. In 2015-16, a total of 69 publications were issued by JRC involving India in various areas and fields interfacing science, technology and society and policy issues. Policy and innovation are the main thrust of JRC's acitivities in India which interface with various Indian institutions. The Table 15 lists some of the excellent organizations in the area of the science to policy interface (boundary organizations) in India. These are the institutions with which JRC could link up its activities. JRCs cooperation with Indian institutions and the number of projects or studies in various areas are shown in Table 16. There are various studies concerning India are undertaken by various JRC institutes. These studies or projects may be or may not be in cooperation with Indian institutions. This is shown in Table 17. The Table 18 depicts emerging influential S&T institutions in India.

Table 15: Excellent organisations in the area of the science to policy interface (boundary organisations)

S.No	Public Science Agencies/Type of Institution	Area of expertise
1	International Collaboration Division Department of Science and Technology Ministry of Science and Technology, New Delhi	Science Diplomacy; Science Management; Networking and cooperation; international relations
2	Industrial R&D Programme, Unit, Department of Scientific and	Technology Transfer, Innovation, networking and cooperation

106 http://eeas.europa.eu/delegations/india/documents/h2020_brochure-india-aug_2014.pdf

	Industrial Research, Ministry of Science and Technology, New Delhi	
3	Technology Information Forecasting and Assessment Council (TIFAC, DST), New Delhi	Foresight studies, Evaluation studies, socio-economic impact of S&T
4	Department of Industrial Policy and Promotion, Ministry of Commerce and Industry, New Delhi	Industrial and R&D policies
	Research and Higher Education	
5	Centre for Studies in Science Policy, Jawaharlal Nehru University, New Delhi (Postgraduate research and teaching department)	Science and technology policy studies, innovation, research and innovation policies, comparative science and technology policy studies, environment and development; socio-economic impact of S&T; regional studies in S&T; renewable energy
6	National Institute of Advanced Studies, Bangalore	Space and aerospace policies
7	National Institute of Science, Technology and Development Studies, CSIR, New Delhi	Science and technology policy studies, scientometrics,
8	Centre for Development Studies, Thiruvananthapuram, Kerala	Innovation Studies and S&T policies
9	Tata Institute of Social Sciences, Mumbai	Disaster management, climate change, environment and development; natural resource management
10	University Grants Commission & Ministry of Human Resource Development	Higher Education and research in Universities, skills and entrepreneurship education
	Non-Governmental Institutions	
10	Prayas Energy Group, Pune, India	Renewable energy
11	Centre for Science and Environment, New Delhi	Environment and development; climate change; water; natural resource management
12	National Association of Software Companies, New Delhi	ICT policies, Software and big data policies
13	National Institute for Transforming India (NITI) Ayog	Policy planning and national development strategies

Table 16: Organisations in areas of the current cooperation between the JRC and the Indian Institutions

S.No	Area	Agency/Organization/Institution	Projects/studies
1	Economy, finance and markets		na
2	Energy and transport	Indian Institute of Technology, Delhi	21
3	Education, skills and employment	na	-
4	Food, nutrition and health	Department of Biotechnology (Vaccine Development)	6
5	Environment, resource scarcity, climate change and sustainability	Department of Biotechnology, Department of Science and Technology, New Delhi	37
6	Disaster risk management, nuclear safety and severe accident research	Bhabha Atomic Research Centre, Mumbai	10
7	Migration and territorial development	na	-
8	Data and digital transformations	Ministry of Information and Communication Technology, New Delhi; Anna University, Chennai	
9	Innovation systems and processes	Centre for Studies in Science Policy, Jawaharlal Nehru University, New Delhi; CSIR, New Delhi; DBT; DSIR	8
10	Space Research; International color coding group;	Indian Space Research Organization, Bangalore	1
11	Standards	na	5
12	Agriculture and Food Securtity	Indian Council of Agriculture Research, ICRISAT, Hyderabad	5
13	Information Society	Department of Information and Communication Technology	11

Table 17: JRC Institutes which have undertaken studies on India

JRC Institute	No of Studies
IPTS	42
IES	35
IET	21
IPSC	8
IRMM	6
IHCP	2
ITU	1
Total	115

Table 18: Emerging Influential Institutions in Science, Technology and Higher Education

S.No	Institution	Area/Field
1	Indian Space Research Organization	Space research and innovation
2	Atomic Energy Agency	Nucelar research and innovation
3	Department of Science and Technology	Scientific research and nodal agency for S&T
4	Department of Scientific and Industrial Research	Industrial research
5	Defence Research and Development Organisation	Defence research
6	Indian Council of Agricultural Research	Agriculture research
7	Indian Council of Medical Research	Medical research
8	Department of Biotechnology	Biotechnology
9	Department of Information and Communication Technology	ICT and software
10	Department of Electronics	Electronics
11	Department of Telecommunications	Telecom and National Knowledge Network
12	Ministry of Skill Development	Skills and Training
13	Ministry of New and Renewable Energy	Renewable energy in solar, wind, biomass R&D and innovation
14	Nuclear Power Corporation	Nuclear energy and innovation
15	University of Grants Commission	Higher education and R&D
16	All India Council for Technical Education	Technical higher education and R&D

17	Antrix Corporation	Space innovation and commercialisation
18	Ministry of Earth and Ocean Sciences	Earth and ocean research and innovation
19	Department of Ayurveda, Yoga, Naturopathy, Unani, Siddha and Homeopathy	Indigenous medical systems and innovation
20	Global Innovation Technology Alliance, Department of Science and Technology	Globalization of R&D and Innovation
21	National Institute for Transforming India (NITI) Ayog	National development strategies in R&D and innovation
22	National Informatics Centre	E-governance, digital diffusion and advance communications

5.4 R&I linkages between countries in this study

The genesis of science, technology and innovation cooperation between India and European Union dates back to 1960s. In terms of first instruments of agreement between India and EU signed in relation to cooperation was the *Joint Statement of 1993* which was carried forward with a formal agreement in 1994. It was this time phase and this agreement which helped India to start participation in EU framework program FP4 which ran from 1994-1998 and in which India and EU had total of 33 projects. This participation further paved the way of India's participation in FP5 programme from 1998-2002 in which there was total of 32 projects of science & technology cooperation between India and EU.[107]

It was during the phase of FP5 program that the both India and EU agreed upon the first formal agreement specifically dedicated to science & technology cooperation in 2001 called *'European*

Community-India Science and Technology Agreement'. [108] This was the major S&T cooperation agreements signed between both the sides which opened the scope and domain of future S&T cooperation. After signing of this formal mechanism of international S&T cooperation the total number of projects between India and EU doubled in the FP6 framework programme during 2002-06 having 60 projects compared to 32 projects of FP5 programme. This was another phase which marked some further developments in India – EU science & technology cooperation. During 2005 a joint action plan was signed and which also catered to the five important India – EU coordinated S&T calls which opened new vistas of S&T cooperation. In 2008 special pilot initiatives under the domain of EU Strategic Forum for International Science and Technology Cooperation was launched.[109]

The latest instrument of agreements between India and EU is the agreement of joint declaration in 2012. Some of the prominent areas of cooperation between India and European Union have been related to health & medicine, food & agriculture, ICTs, Nano-technologies, Energy, Environment, Transport, Space and Nuclear.

S&T agreements and collaborations between India and EU given under section 5.2. Section 5.3 gives various fields in which cooperation has taken place. Various other

107 V.V. Krishna (with the assistance of Rajiv Mishra) *India S&T Cooperation with EU and Other Select Countries*, Centre for Studies in Science Policy - Jawaharlal Nehru University New Delhi, Report Commissioned by Centre for Social Innovation, in the framework of Indigo Policy (FP7) Vienna, 2015
108 Ibid.
109 Ibid.

instruments and mechanisms such as bi-lateral, multilateral and joint laboratories etc. are given under Section 5.2.2. Some data on funding are also given in Section 5.2.

5.5 Researcher mobility and joint laboratories

5.5.1 Researchers from abroad and national researchers

International cooperation in science & technology is also very much impacted with the cross flow of researchers and students from one country to another. The main science agency which is responsible of researchers and scientists mobility is the International division of department of science and technology and also other bodies under ministry of science and technology like Council of Scientific and Industrial Research, (CSIR) and Department of Biotechnology. India in its domain of scientific collaboration with some important S&T partners like EU, USA, Germany, France, Australia and UK provides reflections on various programs and mechanisms for researchers and scientists mobility. Firstly, we will explore USA, Germany, France and UK and then discuss the scientific and technological research exchanges and mobility with EU.

USA

India and USA have some specific programs of science technology collaboration which cater to researchers' mobility. Science and Technology cooperation between India and USA under the platform of IUSSTF (India-US Science & Technology Forum) has several scientists, researchers and students flow in the various fields of science & technology. Research and study visit programs such as women in science entrepreneurship & research, Silicon Valley experiential learning program for women entrepreneurs, IUSSTF professorship in Microbiology, American Physical Society Fellowship, Students- Research Internship in Science and Engineering (RISE), Bhaskara Advanced Solar Energy fellowship programs, Khorana Program for scholars, viterbi India program, graduate research opportunities worldwide program and S.N Bose scholars program are some of the important science and technology exchange cooperation mechanisms under which Indian and US scientist, researchers, entrepreneurs and students interact.[110]

The Indo-US Science and Technology Forum (IUSSTF), established under an agreement between the Governments of India and the United States of America in March 2000, is an autonomous, not for profit society that promotes and catalyses Indo-US bilateral collaborations in science, technology, engineering and biomedical research through substantive interaction among government, academia and industry.[111]

India and UK

The Department of Biotechnology is collaborating with Wellcome Trust (WT), which is a London-based "global charitable foundation dedicated to achieving extraordinary improvements in health by supporting the brightest minds". The partnership is for launching three-tier fellowship programme on biomedical research at post-doctoral level. The DBT and the WT, each have committed 8 million pounds per year, for a period of five years with effect from 2015.[112]

Four categories of fellowships are awarded every year:[113]

- 40 Early-career fellowships (with one year post-doctoral experience)
- 20 Intermediate fellowships (with 3-6 years of post-doctoral experience)
- 10 Senior Fellowships
- Six renewals of ongoing senior fellowships every year
- Margdarshi fellowships

110 http://www.iusstf.org/cms/gall_content/2016/1/2016_1$PDF127_Jan_2016_131456857.pdf

111 Ibid.

112 http://www.wellcomedbt.org/

113 http://www.wellcomedbt.org/

Table 19: Showing number of Indian and American exchanges in different education and research programs.

Program/Project of Exchange	No. of Indian Students/ Scientists	No. of American Students/ Scientist	Total
IUSSTF-Microbiology Professorship	2	3	5
American Physical Society	3	4	7
RISE (for American students)	-	5	5
BASE (for Indian students)	22	-	22
Khorana Program for Indian students/researchers	30	-	30
Viterbi Program for American Students	20	-	20
S.N Bose Fellowships	56	10	66
Total	133	22	155

Source: Table generated and computed from IUSTFF Annual Report.

India and Germany

Scientific exchanges between India and Germany outside the domain of EU framework cooperation is done through a dedicated platform called Indo-German Science and Technology Centre (IGSTC).[114] Using this platform mobility based S&T cooperation projects is carried out by German BMBF International Office and DAAD (projects based exchanges) which includes specialists' scientists and researchers visits. Under this program of scientific personnel exchanges were done for 20 projects in 2013-14. This mobility projects are jointly funded by German academic exchange (DAAD), BMBF office and department of science & technology government of India. [115]

India and France

India and France also have mechanism for science and technology cooperation in terms of research mobility for scientists and students. Indo-French Centre for the Promotion of Advanced Research has two important research mobility based programs called ESONN (European School of Nano-Science & Nano-Technologies -CEFIPRA Fellowship Programme. First one is funded by CEFIPRA in association with French Université Joseph Fourier and second is funded by department of science & technology, government of India and department of science & technology of the Embassy of France in India. In the year 2013-14, 6 Indian research students participated and travelled to ESONN. Furthermore, in the same time period of 2013-14 a total of 16 research students from India and France got selected for Raman Charpak Fellowship Programme in various fields

114 http://www.igstc.org/about_us.html
115 IGSTC-Annual-Report-2011-12, Indo-German Science & Technology Centre.

of science & technology. Out of the 16 doctoral students, 11 students were from India and 5 from France.[116]

Indo-French Centre for the Promotion of Advance Research (IFCPAR) is a bilateral institution of cooperation in Science and Technology. The Centre established in 1987 receives financial support from the Department of Science & Technology, Government of India and the Ministry of Foreign Affairs, Government of France. This institution is physically located in New Delhi.

Global Innovation and Technology Alliance (GITA): Platform for Joint Funding in STI[117]

GITA, on behalf of the Department of Science and technology, Government of India extends financial support in the form of soft loans and grant to the Indian Applicant for joint R&D, scientist exchange programmes etc. Counterpart agencies implement the programme in the partnering country. The main objective of the Joint R&D programme is to stimulate, promote and support Industrial and Institutional R&D for the mutual benefit of Indian and international counterpart.

The concept of 'brain drain', 'brain bank', 'brain gain' and finally 'brain circulation' in relation to India has been an issue from the past in the policy discourse at various times reflecting the situation in various phases. From around 1960s to 1980s various studies consider this as the phase of brain drain.[118] The situation of India's leading Indian Institutes of Technology clearly depicts this stark phase of brain drain. The 1986 Review Committee Report on IITs indicated that during 25 years the institutions produced 27,000 graduate engineers. Two important studies by Sukhatme and Mahadevan (1987) and Ananth et al. (1989)[119] on IIT Bombay and IIT Madras, respectively, substantiated the extent of brain drain in institutions of higher learning. The data on IIT Bombay for the mid-1980s reveal that approximately 37% of undergraduates and 31% of postgraduates went abroad after engineering studies and only a small percentage that is, between 3% and 7% returned to India. Study on IIT Madras done by Ananth et al. (1989) reveals alarming facts. Since its inception in 1959, the proportion of IIT Madras graduates emigrating abroad was shown as 26%. The extent of migration steadily increased from 20% during 1968-72 to 35% during 1983-87. Speciality-wise, migration varied from a minimum of 18.4% in aerospace engineering to a maximum of 44.6% in chemical engineering.

The country witnessed considerable economic growth and development of S&T infrastructure coupled with the emergence of science community and intellectual climate in the 1990s. These developments reversed the process of brain drain to some extend drawing attention to the phase of brain gain. India witnessed two phases of brain gain. In 1950s and 1960s the first Prime Minister, Jawaharlal Nehru, made relentless efforts to attract several Indian scientific elite from abroad to take charge of emerging Indian science enterprises. The other phase of brain gain began in the 1990s.

It was only towards the end of the 1980s and in early 1990s brain gain as a concept again came into focus. The study by Krishna (1996) indicates efforts to establish biotechnology in India in the late 1980s and subsequent pro-active policies of Department of Biotechnology in the 1990s led to further strengthening the innovation system of agriculture, health and pharma related biotechnology. The Survey of 13 research groups in biotechnology established that institutionalization and growth of specialist communities over a period came about as a result of several well-known

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116 http://www.cefipra.org/indofrench_cms/newsimages/file/CEFIPRA_AR%202014_15.pdf

117 http://gita.org.in/aboutus.aspx#incorporation

118 See Salam, A (1966). The isolation of the scientist in developing countries. Minerva Summer 1966, Volume 4, Issue 4, pp 461-465; 53).Also see, Krishna, V. V. and Khadria, B. (1997). Phasing Scientific Migration in the Context of Brain Gain and Brain Drain in India, Science, Technology & Society, July–Dec.

119 Sukhatme, S.P. and Mahadevan I (1987), Pilot Study on Magnitude and Nature of the Brain-Drain of Graduates of the Indian Institute of Technology, Bombay. Bombay: Indian Institute of Technology. See Ananth, M.S, Ganesh Babu K and Natarajan R (1989). Data Base for Brain-Drain: Institution Based Study, IIT Madras. Madras: IIT.

Indian biologists from abroad began specialist groups in various institutions.[120] Several institutional measures and government programmes also came about after 1990s which have aided the process of brain gain.

TOKTEN (Transfer of Knowledge through Expatriate Nationals) programme in the 1990s is one of the important policy measures. This programme enables non-resident Indian (NRI) professionals to spend between four to eight weeks in Indian institutions. This scheme is mediated through the INRIST (Interface for NRI Scientists and Technologists) centre established under the CSIR in 1990 by the Indian government. The Department of Science and Technology (DST) instituted two major schemes in the form of "Ramanujan Fellowships" and "Innovation in Science Pursuit for Inspired Research (INSPIRE)" to attract researchers and scientists working abroad in the post 2000.

Ramalingaswamy Re-entry Fellowship scheme was initiated in 2006 by DBT for Indian scientists who were working in overseas institutions and universities. The scheme enabled scientists who would like to return to India to pursue their research interests. Khadria's (2002) study also reveals that there is a positive trend of return migration among Indian IT Professionals in the era beginning late 1990s[121]. This study revealed two surveys. The survey on IT professionals in the city of Bangalore and their role in making the city a corridor for international mobility of Indian professionals; and the second survey of health professionals (doctors and nurses) in the city of New Delhi give ample evidence to the process of brain gain. The scheme of Software Technology Parks of India and other related policies in 1995 gave thousands of IT firms a 10-year tax holiday, which were kept extended and was valid till 2010. Further thrust to computer industry is provided in terms of progressive reduction in duties, where the state reached zero duty regimes in computer products by 2003.

In the last decade (2005-2015), the phenomenon of brain circulation has come into sharp focus in migration studies. Brain circulation is associated with knowledge-based society and catalysed by the ICT revolution in a large measure in the Indian context. Another important source of brain circulation, particularly in ICT software sector, has been the role of two major professional associations located in Silicon Valley, USA and their collaborative and business links with software hubs such as Bangalore, Hyderabad, NCT Delhi, Pune, and Chennai through software industry association called NASSCOM. The Indian community in fact institutionalised social networks and its links with the Indian ICT clusters since the 1990s through formation of two vibrant associations such as the Indus Entrepreneurs (TiE) and Silicon Valley Indian Professional Association (SIPA) both head quartered in Silicon Valley, California. One significant feature of the Diaspora connectivity was in catalysing the process of Venture Capital policies and schemes. The booming software export sector in India, which in 2016 stands at US $ 150 billion and the ICT infrastructure that underpinned it has attracted hundreds of professionals in recent years to establish new software firms in India. The trend in software and biotechnology sectors has been characterised more recently as 'brain circulation or 'brain gain'. NASSCOM has indicated that there are about 1000 firms in software and services established in India by professionals who have returned back to India or who continue to live abroad and keep circulating to and from.

The government has committed 2% of GDP to R&D but such public policies are yet to be implemented. Unless research intensity in universities is not increased by two or three times and provide more incentives to scientists and engineers, India might again confront the problem of professional flight. Directly or indirectly these improvements in

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[120] Krishna, V V. 1996. Brain Drain, Brain Gain and Scientific Communities: Indian Experience in the Field of Biotechnology. *Charum J, Meyer JB,(éds.)* International Scientific Migration Today, Proceeding of the international symposium held in Bogota.

[121] Khadria, B. (2002). Skilled labour migration from developing countries: Study on India, *International Migration Papers*, No. 49, International Labour Office, Geneva.

R&D spending and strengthening of research and innovation eco-system will go a long way to curb and arrest brain drain and aid brain gain and circulation.

5.5.2 Scope of joint laboratory collaboration in country or in Europea

The scope and feature of India-EU collaborative laboratory work could be discussed with a specific cooperation program called *INDO MARECLIM Project.*[122] INDO MARECLIM which stands for 'Indo-European Research Facilities for Studies on Marine Ecosystem and Climate in India' a project work under the EU INCO-LAB call was started to be built from 1998 in the Nansen Environmental Research Centre-India (NERCI) in Cochin, Kerala. There are collaborations with some other Indian partners which include Indian National Centre for Ocean Information Services (INCOIS), Anna University, Cochin University of Science and Technology (CUSAT), Kerala University of Fisheries and Ocean Studies (KUFOS), and Toc H Institute of Science and Technology (TIST). The EU partners in this joint laboratory project are Nansen Environmental and Remote Sensing Centre Norway (NERSC), Plymouth Marine Laboratory UK (PML), Centro Euromediterraneo per i Cambiamenti Climatici Italy CMCC, Institut Francais de la Recherche Pour l´Exploitation de la Mer IFREMER, France and Stichting Dienst Landbouywkundig Onderzoek, The Netherlands.[123] This joint lab work and is operated and funded with the help of a consortium of five EU partners mentioned above and the Indian partner in Cochin, Kerala in association with other Indian collaborators. This project is funded under the EU FP7 framework cooperation programme specifically under Inco-Lab project. Under the larger umbrella of marine ecosystem INDO MARCELIM project incorporates joint lab research on.[124]

- Marine eco-system incorporating algae bloom.
- Coastal zone management and societal impact.

The policy approach to the INDO-MARCELIM project is with reference to EU FP7 programme specifically funded under Inco-Lab call, which tries to create a model EU-India joint laboratory collaboration in the field of monsoon, climate change and marine eco-system. This is also done to use the Norwegian Institutional infrastructure and scientific cooperation with India which dates back to 1998 and to extend it to a wider network of European Union researchers and scientists working in the same area. The use of the existing network and built cooperation between India and Norway itself shows the nature of difficulty in establishing a joint laboratory from scratch within the current framework of cooperation.

There has been 3 co-publication from the INDO-MARCELIM project where 2 publications where done in 2013 and 1 in 2015. [125]

5.6 R&D related FDI

Indian economy opened up in 1991 by coming to the era of liberalisation and globalisation. With this doors of Indian economy were made widen open under the WTO/GATTs agreement and India removed structural barriers for foreign investments in India. The impact of economic liberalisation of 1990s and start of IT business investments in India showed its early results when MNCs (Multi National Corporations) from mid 2000s started building their R&D facilities in India in which Texas Instruments was the first in process. It was during this time that UNCTAD (United Nations Conference on Trade and Development) survey in 2005 ranked India as the 3rd most preferred countries for R&D activities. As per a latest global R&D study done by Zinnov consulting,

122 http://ec.europa.eu/research/iscp/index.cfm?pg=india
123 http://indomareclim-nerci.in/
124 Ibid.
125 http://indomareclim-nerci.in/publication.php

India is among the top 5 hotspots of global R&D activities which is worth of $ 31 billion dollars in which India's share potential is $12.5 billion dollars.[126]

In this relation the latest FDI policy move by the current government tries to align favourable FDI conditions for overall economic growth and development of India. The broader goal of faster industrial development resulting in better economic growth is being aligned with a new FDI policy called '*Consolidated Foreign Direct Investment Policy, 2015'.*[127] This FDI policy measure tries to create favourable grounds for foreign direct investment for the purposes of creation of capital, technology and entrepreneurship development. Some of the important sectors which are being covered under this latest FDI policy measure are manufacturing, pharmaceuticals, defence, services and energy.[128] These sectorial areas getting attention from the current government is also an integrated measure of the government to align latest FDI policy with flagship programs such as *Make in India, Digital India, Skills India* and *Clean India.*

Table 20: Overview of FDI during the time phase of 2003-2009

	2003	2004	2005	2006	2007	2008	2009	Total*
No. of investments	348	486	437	627	512	686	344	3467
No. of countries	32	33	38	39	38	51	37	
Total FDI	19.79	36.73	29.74	89.14	56.85	80.54	37.68	350.47
(in billion USD)**	(5.65)	(10.48)	(8.49)	(25.43)	(16.22)	(22.98)	(10.75)	(100)

Source: CSIR-NISTADS-TIFAC Data (2011)

Table 21: Overview of FDI in R&D

Year	No. of investments	No. of source countries	Investment (billion USD)	Share in total FDI (%)	Sector
2003	103	13	2.18	11.02	19
2004	182	15	3.19	8.68	17
2005	140	13	2.66	9.68	13
2006	192	23	10.63	11.93	22
2007	131	16	3.37	5.93	17
2008	114	23	3.61	4.48	23
2009	75	13	3.56	9.45	22
Not specified	27	16	0.02		13
	964 (total)		29.22 (total)	8.25 (average)	

Source: CSIR-NISTADS-TIFAC Data (2011

126 http://zinnov.com/global-rd-service-provider-ratings-2015-2/
127 http://dipp.nic.in/English/policies/FDI_Circular_2015.pdf
128 Ibid

Table 22: Sectorial Patterns of FDI in R&D

Sector	Percentage share of FDI
Aerospace	3.26
Auto industry	8.7
Pharma and biotechnology	1.4
Real estate and construction	11.33
Machinery and equipment	1.86
Services	5.16
Chemicals	1.54
Metals and minerals	27.01
Software and IT	13.79
Electronic components	1.99
Engines and turbines	2.4
Tourism and entertainment	3.1
Transportation	6.62
Warehousing and storage	5.1
Others	6.73

Source: CSIR-NISTADS-TIFAC Data (2011)

5.7 Assessment

The EU and India have had an S&T Agreement since ten years and significant cooperation happened in FP4 to FP7 joint projects. Currently Indigo and Horizon 2020 projects programs are in operation. This decade-long research collaboration has generated considerable research and innovation potential. From the perspective of knowledge, India-EU multilateral cooperation not only advanced scientific knowledge but also was very useful in addressing various mundane socio-economic and technical problems in various fields of science and technology in the Indian context. Particular mention may be made of S&T projects on water, environment, ecology, sustainable development, energy, health etc.

A good deal of research output has been produced in the EU-India cooperation projects, both in the form of joint research papers and patents in several S&T areas.[129] Much of the research output and knowledge already generated exists in fields such as water, environment, biotechnology, ICT, health, energy, among others. There is a good ground to say that EU-India cooperation projects have generated research and innovation potential relevant to India's main flagship programmes like Clean India, Green India, Smart Cities, Digital India and several other areas such as infrastructure and transportation. In other words, there is an enormous amount of demand existing to convert and realize the research and innovation potential within India's new policy priorities. Dr João Cravinho, head of EU office in New Delhi in 2015 already expressed his positive sentiments pointing to smart cities, digital India, cleaning Ganga etc.

A major benefit of EU-Multilateral S&T Cooperation compared to other bilateral projects has been India's equal partnership in EU based 'big science' (ITER and FAIR projects) and 'high technology' projects. Without the progress of EU-India cooperation and commitment to take the cooperation to higher level on both sides, this entry of India to this large scale EU driven multilateral big projects was not possible. The very volume and density of the cooperation increasing also automatically expands the domain of Indian participation in 'Big Science' areas with European Union and also to share its own expertise with European Union. Indian Physicist, Nuclear Scientists, and Astrophysicist to name some big science experts are known world over for their work. This project provides Indian institutions and scientists and engineers a unique opportunity to work on cutting edge scientific research through these large EU programmes.

[129] For instance see Policy Brief- Co-Patenting in India, by Florian Grubber and Florina Piori, Indigo Policy, CSI, Austria.

The impact of EU-India S&T projects and cooperation will be determined by creating institutional mechanisms and instruments for promoting linkages and innovation. Presently the innovation potential underlying the S&T cooperation projects has not been fully realised. On the other hand, new cooperation through S&T projects in the coming years could be conceptualized taking into account not only the new flagship programmes in India but incorporating institutional mechanisms to connect R&D with innovation.

From the organizational and structural perspective, EU-India multilateral cooperation and S&T Agreement enabled scientists, academics and professionals on both sides to come together under a single laboratory-platform to pursue R&D work. Joint project workshops and exchange of students and researchers (Marie Curie and Mundus) in many ways created a very important intellectual medium for discourse and mutual understanding.

6. Conclusions

India’s national innovation system has a well-articulated institutional framework to meet multitude of national and global challenges aided by one of the fastest growing economies in the world. The new government, which has taken over in 2014, has initiated a number of flagship programmes with a clear objective to bring about structural changes both in the economy and society. However, the national innovation system is somehow constrained to fully realize it's potential. From a systemic perspective one can identify some weak links.

- Public and private R&D funding including the higher education R&D is the heart of the NIS. Even though the national economy doubled over the last 10-12 years, R&D intensity remained somewhat stagnated below 0.9%. By all estimates this figure is not only far below the dynamic lead countries in Asia, Europe and North America but has prevented NIS to fully unleash its potential meet India’s national and global challenges. For instance, the government has announced a series of national flagship programmes (see section 1.2) but they lack adequate R&D and innovation back up and funding to fully realize their potential. It is high time that the government raise the R&D intensity to a committed level of 2%.

- With over 700 universities and 30 000 colleges, India’s higher education system continues to remain a weak link in the NIS. Much of it's under utilization and low impact potential for industry emanates from again the very low research intensity. More than 85% of the universities and colleges by and large remain as teaching institutions and are yet to attain the Humboldtian goal of teaching and research unity. Innovation culture is just emerging in the 15% of the higher educational institutions which in a relative sense have a medium to strong research intensities. Given this situation universities are able to only play a marginal role in university-industry relations.

- There exists a well-articulated institutional STI policy framework but the linkages between different actors within the national innovation system are rather weak and operate in relative isolation to each other. Institutional mechanisms connecting various actors (business, public and private R&D, higher educational institutions and NGOs do exist but they operate at sub-optimum level. For instance, following the policy discourse initiated by the Prime Minister’s office, the finance ministry allocated budgets for half dozen flagship programmes. However, the linkages and signals to public and private R&D, particularly to S&T related ministries are rather weak.

- The ministry of S&T and related departments under it has a large number of tax incentives, schemes and policy measures for private business enterprises but from an overall perspective the system lacks accountability and in some case penal support (for tax incentives to private sector for instance).

- More than 55% of GERD is spent on nuclear energy, space, defence related strategic science agencies but their linkages to private and public industry and S&T institutions is very weak. There is lot of innovation potential that exists in these three sectors which remain to be exploited for national development.

- NIS in a large measure enabled the country to register high growth rates of economy in several sectors. The high growth rates in the last decade also led to increasing inequalities and rising poverty levels in the population. There is over 90% of labour force in the informal sectors of economy and a significant proportion of India’s GDP (between 20 to 25%) comes from semi urban, agro-industrial and rural enterprises including more than 2000 industrial clusters. Generating employment and skills to enhance economic levels of nearly 600 million people poses a gigantic challenge for STI policies. The government both in the 12^{th} Plan (2012-2017) and the recent 2016 budget has underlined the importance of inclusive growth and inclusive innovation. Here again the linkages within rural innovation systems and between rural and national innovation systems are weak. The government is well aware of the importance underlying these links but the movement to forge them and implementation part is moving rather slowly.

There is a good policy mix in place within the broad framework of STI policies of NIS and particularly emanating from other ministries ranging from railways, infrastructure, rural development, telecommunications to transport etc. The major problem has been the interaction and operational linkages between different actors of the NIS. Sections 1.2 and 2 and 3 have identified a series of policies, policy measures and schemes to address various structural challenges noted in section 6.1 above. Whilst it may be taken that the mix of policy measures are indeed adequate to address challenges on hand, two major constraints emanate from operational part and the process of coordination and accountability. For instance, the policy thrust of PPP mode in raising R&D intensity from 0.88 to 2% has not come about in the last two years and this national figure remains relatively stagnant. Various policy measures such as R&D tax incentives to the extent of 150% are existing to enhance the participation of business and private industrial firms but these tax incentives lack penal support and accountability.

Micro and SME sectors together with the policies on inclusive have suffered due to change in the government between 2014 and 2015 and corresponding policy regimes. For instance, India Inclusive Innovation Fund launched by earlier government suffered abortion due to change in the government and policy regime. The new policy regime which enhanced the corpus of fund relevant to these sectors covering inclusive innovation and introduced in different policy mixes (see Atal Innovation Mission, SETU and Startup schemes – section 1.3) are yet to take off the ground and get into operational steam.

Similarly, a mix of policy thrust to increase the research intensity in the academic sector has not witnessed any major boost to R&D in higher educational institutions in the last two years. Various schemes and policy measures to commercialize publicly funded research in universities remain at a very low level due to lack of effective mechanisms to bridge linkages between universities and public research institutions on the one hand, and between universities and industry on the other. Whereas the impact of existing policy measures to bridge the linkages between universities with other actors of NIS remain at a low key, the existing innovation potential in the universities and public research systems have not been fully exploited due to lack of adequate IPR measures. Indian version of Bahy Dole Act which was supposed to bring about some common or homogeneous IPR policy to regulate research and innovation in public research and higher educational institutions is still pending in the Parliament.

There are policy mixes which have been quite effective in boosting innovation and sustaining safety and risk in technology. For instance, India's space policy combined with a range of policies and incentives to partner business enterprises led to very successful space innovation programmes. India can now boast of a thriving commercial space applications and launch of Indian and foreign satellites. Similar is the case with the success of software sector which now contributes over 7% of India's GDP. In the area of averting risk and sustaining safety, mix of policies and institutional measures have prevented the introduction of GM technologies in food (BT Brinjal) due to incomplete risk related studies. A series of policy mixes was involved in this case beginning from the regulatory institution of GM technologies, agriculture policy regimes, India's Parliamentary Committee norms and recommendations, various farmers representatives and civil society discourse leading up-to to submission of reports to the government and ultimately the Supreme Court's technical evaluation committee which called for a series of risk related studies and specific bio safety protocols.

Main strengths and weaknesses can be summarised as follows:

Strengths

- India’s rapidly growing middle class, urbanisation and expanding markets coupled with highly skilled and low wages makes an attractive destination to FDI in R&D
- High level of knowledge and technological capabilities in pharma, auto, software, aerospace and satellite design and launching has enabled India to become competitive at the global level. India’s capabilities in reverse engineering and production of generic drugs are very high.
- Software, professional, medical and engineering services with high skilled workers at low wages is a major attraction to world markets.
- Emerging venture capital funds and angel investors
- A highly developed framework for NIS and research and innovation policy measures

Weaknesses

- Medium level of funding R&D intensity is a constraint to infuse new research and innovation capacities
- Government commitment to double R&D/GDP (2%) – implementation process is very slow
- The quantum of project based funding is low compared to block grants
- The quantum of funding devoted to civilian R&D is low compared to strategic R&D
- Research intensity in academic sector is very low (about 5-7%) compared to government research agencies (64.4%) in GERD
- Slow implementation of IPR in universities as bill is still pending in the Parliament
- Compared to OECD and other emerging economies, business enterprise R&D proportion of GERD is of low level.
- R&D tax incentives lack penal underpinning to ensure firms undertake R&D rather than quality control, technical activities etc.
- Public – Private Partnerships in R&D and Academy – Industry partnerships are underdeveloped
- Weak research accountability and evaluation in public research system
- Linkages between public procurement and R&D institutions and universities very weak.
- Weak regional policies and low level funding for industrial clusters and SMEs sectors.
- System of governance in setting research priorities, S&T forecasting and preparing strategic research and innovation plans is highly developed but lacks adequate mechanisms of interaction and linkages.

As already noted in section 3.4 there are three pathways for a fruitful R&I collaboration between Indian and EU and its member states.

- EU-India cooperation projects have generated research and innovation potential relevant to India’s main flagship programmes like Clean India, Green India, Smart Cities, Digital India and several other areas such as infrastructure and transportation. In other words, there is an enormous amount of demand exists to convert and realize the research and innovation potential within India’s new policy priorities. The impact of EU-India S&T projects and cooperation will be determined by creating institutional mechanisms and instruments for promoting linkages and innovation in the coming decade.

- Beyond the EU-India S&T cooperation projects, a new pathway has already emerged for various European countries and India partnerships based on private firms, business enterprises and public enterprises. There is immense innovation potential to be exploited in half dozen new flagship programmes.

- India is a home for more than 1070 multinationals (more than half from European and North American) R&D centres or laboratories. All leading firms are collaborating with Indian public and private firms for global innovation, manufacturing and marketing. Indian has emerged as an important nodal point in the global chain of distributed innovation networks. Bulk of global innovation these days takes place in this mode of collaboration and partnerships. There is a fruitful ground exists for EU's R&I programmes to link up and partner with this India based global innovation chain.

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Abbreviations

EU: European Union

GDP: Gross Domestic Product

FDI: Foreign Direct Investment

US: United States

DMIC: Delhi-Mumbai Industrial Corridor

GERD: Gross Expenditure on Research & Development

PPP: Public Private Partnership

R&D: Research & Development

STIP: Science, Technology and Innovation Policy

IAPP: Industry-Academia Partnerships and Pathways

ICT: Information & Communications Technologies

NKN: National Knowledge Network

NOFN: National Optical Fiber Network

AMRUT: Atal Mission for Rejuvenation of Urban Transformation

DIPP: Department of Industrial Policy and Programme

CEO: Chief Executive Officer

ITN: Initial Training Networks

IIF: International Incoming Fellowships

IRSES: International Research Staff Exchange Scheme

UID: Unique Identity

GIS: Geographical Information Systems

OGPC: Open Government Platform

CBIC: Chennai-Bangalore Industrial Corridor

AKIC: Amritsar- Kolkata Industrial Corridor

SNCF: Société Nationale Des Chemins de Fer Français

SETU: Self-Employment and Talent Utilization

AIM: Atal Innovation Mission

TIFAC: Technology

DRSCs: Department Related Standing Committees

NSTMIS: National Science & Technology Management Information System

NCR: National Capital Region

TUDPW: Technology Utilization and Development Programme for Women

OECD: Organization for Economic Cooperation & Development

IGIB: Institute of Genomics and Integrative Biology

UGC: University Grants Commission

AICTE: All India Council for Technical Education

SERB: Science & Engineering Research Board

ITER: International Thermonuclear Experimental Reactor

FAIR: Facility-for-Antiproton-and-Ion-Research

FPI: Foreign Portfolio Investment

INR: Indian National Rupee

MW: Mega Watt

PV: Photo Voltaic

WTO: World Trade Organization

GATTs: General Agreement on Trades & Tariffs

TIETS: Technology Incubation and Entrepreneurship Training Society

SINE: Society for Innovation and Entrepreneurship

TBIU: Technology Business Incubation Unit

TCS: Tata Consultancy Services

BISS: Bio-Incubator Support Scheme

IT: Information Technology

RIS: Regional Innovation Systems

DeiTY: Department of Electronics and Information Technology

SAC: Special Advisory Committee

NITI: National Institution for Transforming India

DAE: Department of Atomic Energy

DoS: Department of Space

ISRO: Indian Space Research Organisation

MoS&T: Ministry of Science & Technology

MoHFW: Ministry of Health & Family Welfare

MoES: Ministry of Earth Sciences

MoCIT: Ministry of Communications & Information Technology

MoD: Ministry of Defence

MoEFCC: Ministry of Environment, Forests and Climate Change

MoNRE: Ministry of New and Renewable Energy

MoWRRDGR: Ministry of Water Resources, River Development and Ganga Rejuvenation.

MoMSMEs: Ministry of Micro, Small and Medium Enterprises**.**

DST: Department of Science & Technology

DBT: Department of Biotechnology

DSIR: Department of Scientific and Industrial Research

DHR: Department of Health Research

DoT: Department of Telecommunications

DoD: Department of Defence

DDP: Department of Defence Production

DDRD: Department of Defence Research & Development

CWET: Centre for Wind Energy Technology

CSMRS: Central Soil and Materials research station

CWC: Centre Water Commission

ICMR: Indian Council for Medical Research

AIIMs: All India Institute of Medical Research

NITs: National Institute of Technology

DRDO: Defence Research and Development Organisation

SECI: Solar Energy Corporation of India

SRISTI: Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI)

IL: Industrial License

IEM: Industrial Entrepreneur Memorandum

SEBI: Securities Exchange Board of India

UIR: University- Industry Relationship

PRS: Public Research Systems

IIT: Indian Institute of Technology

IISc: Indian Institute of Science

SMEs: Small & Medium Enterprises

GAEC: Genetic Engineering Approval Committee

EGNOS: European Geostationary Navigation Overlay Service

GAGAN: GPS and Geo-Augmented Navigation System

PANDA: Anti-proton Anihilation at Darmstadt

NUSTAR: Nuclear Structure, Astrophysics and Reactions

RTD: Research & Technology Development

IBRAD: Institute of Bio-Social Research and Development

IOM-AUC: Anna University Chennai

SICA: Specific International Cooperation

PATSTAT: EPO Worldwide Statistical Patent Database

EPO: European Patent Office

ERA: European Research Area

FETS: Future & Emerging Technologies

DAAD: German Academic Exchange Service

GITA: Global Innovation & Technology Alliance

INCOIS: Indian National Centre for Ocean Information Services

CUSAT: Cochin University of Science and Technology

NERSC: Nansen Environmental and Remote Sensing Centre

UNCTAD: United Nations Conference on Trade and Development

MNCs: Multi-National Corporations

FP: European Framework Programme for Research and Technology Development

ERP Fund: European Recovery Programme Fund

FP4: Framework Program 4

FP5: Framework Program 5

FP6: Framework Program 6

FP7: Framework Program 7

DST: Department of Science and Technology

DBT: Department of Biotechnology

USA: United States of America

IUSSTF: India United States Science and Technology Forum

IFCPAR: Indo – French Centre for the Promotion of Advanced Research

IGSTC: Indo-German Science and Technology Centre

INSA: Indian National Science Academy

ASEAN: Association of Southeast Asian Nations

BIMSTEC: Bay of Bengal Initiative for Multi Sectorial Technical and Economic Cooperation

SAARC: South Asian Association for Regional Cooperation

NAM: Non Aligned Movement

CSIR: Council for Scientific and Industrial Research

EBTC: European and Business Technology Council

CEFIPRA: Indo-French Centre for the Promotion of Advanced Scientific Research.

NSF: National Science Foundation

IUSSTF: India United States Science Technology Forum

S&T: Science and Technology

MOU: Memorandum of Understanding

IOF: International Outgoing Fellowships

IRSES: International Research Staff Exchange Scheme

STREP: Small or medium-scale focused research project

CSIR: Council of Scientific and Industrial Research

DSIR: Department of Scientific and Industrial Research

HEI: Higher education institutions

HES: Higher education sector

NACC: National Assessment and Accreditation Council

PRO: Public Research Organisations

PC: Planning Commission

NITI: National Institution for Transforming India

PRS: Public Research System

R&D: Research and development

SF: Structural Funds

TNCs: Transnational Corporations

UGC: University Grants Commission

USAID: United States Aid for International Development

USISTEF: United States – India Science and Technology Endowment Fund.

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Annex 1 - List of the main Research performers

Rank	Public R&D Performers Based on Publications	Total Number of Papers
1.	IISc, Bangalore	13,685
2.	Bhabha Atomic Research Centre	10, 464
3.	IIT Kharagpur	10,261
4.	University of Delhi	8,497
5.	Banaras Hindu University	7,854
6	IIT Delhi	7,769
7.	IIT Madras	7,742
8	IIT Bombay	7,656
9.	IIT Kanpur	6,888
10.	All India Institute of Medical Sciences	6,624
Rank	Private R&D Performers Based on Expenditure	Total Expenditure

Annex 2 - List of the main funding programmes

Name of the funding programme	Website
Make In India	http://www.makeinindia.com/home
Digital India	http://digitalindia.gov.in/
Skill India	http://skillindia.gov.in/
SETU	http://niti.gov.in/content/setu.php
Atal Innovation Mission	http://niti.gov.in/content/aim.php
Clean India	http://www.swachhbharaturban.gov.in/ISNAHome.aspx
Smart Cities	http://smartcities.gov.in/
StartUp India	https://mygov.in/
Small Business Innovation Research Initiative	http://sbiri.nic.in/
Technology Systems Development Programmes (TSDP)	http://www.dst.gov.in/technology-systems-development-programme-tsdp
Technology Refinement and Marketing Programme (TREMAP)	http://www.step-iit.org/TREMAP.html
Promoting Innovations in Individuals, Start-ups and MSMEs (PRISM)	http://www.dsir.gov.in/12plan/prism/prism.htm
Technology Development and Utilization Programme for Women (TDUPW)	http://www.dsir.gov.in/tpdup/tdupw/tdupw.htm
Patent Acquisition and Collaborative Research and Technology Development (PACE)	http://www.dsir.gov.in/12plan/pace/pace.htm

Centres of Excellence and Innovation in Biotechnology (CEIB)	http://www.dbtindia.nic.in/centres-for-excellence
Biotechnology Parks and Incubators	http://www.archive.india.gov.in/sectors/science/index.php?id=43
Biotechnology and Textiles Clusters	http://www.ibef.org/industry/biotechnology-india.aspx
National Biotechnology Development Strategy	http://pib.nic.in/newsite/PrintRelease.aspx?relid=134035
National Policy on Skill Development and Entrepreneurship 2015	http://www.skilldevelopment.gov.in/National-Policy-2015.html
Deendayal Upadhyaya Gramin Kaushal Yojna (2015)	http://ddugky.gov.in/ddugky/
Atal Innovation Mission	http://niti.gov.in/content/aim.php

Annex 3 - Evaluations, consultations, foresight exercises

Parliamentary Standing Committee on Genetically Modified Crops

http://www.prsindia.org/administrator/uploads/general/1349957427_Standing%20Committee%20Report%20Summary-%20GMO%20Final.pdf

Department of Bio-Technology Evaluations Committee on Bio-safety

http://dbtbiosafety.nic.in/committee/mec.htm

Technology Vision 2035

http://www.tifac.org.in/images/pdf/tv2035/TV%202035%20Doc-Last%20final-release.compressed.pdf

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Stimulating innovation
Supporting legislation

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