Programme on Innovation, Higher Education and Research for Development (IHERD)

Background document

Case study India

Centre of excellence as a tool for capacity building

Draft report

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Executive summary

The OECD has carried out as study on Centres of Excellence (CoE) as a part of the Project on Innovation, Higher Education and Research for Development (IHERD), which is financed by the Swedish International Development Cooperation Agency, Sida.

The development of CoEs is a policy measure, applied by governments in many parts of the world in order to promote a robust research and innovation environment. This is achieved by encouraging institutional profiling and generating a critical mass of researchers. CoE initiatives are a flexible instrument and have been applied in several different ways and for different purposes, such as promoting basic research, innovation, social development and education. Because CoEs are often located in higher education institutions, these initiatives increasingly influence the management of institutions and academic careers.

This CoE case study looks at the system in place in India which began in the 1980s, thus offering a comparison with countries that have long-term CoE strategies in place. CoE schemes in India fall under one of two domains: a) universities under the Universities Grant Commission; and b) science agencies under various ministries.

The first type of CoE scheme is geared towards the professionalisation and advancement of science and training in specialised areas of science and technology such as radio astronomy, astrophysics and nuclear sciences. The second is geared towards research, innovation and specialised services in new technologies and sustainable living in sectors ranging from biotechnology, urban development, defence-related electronics and polymer sciences, telecommunications and ICT.

Preliminary observations from the study of Indian CoEs suggest they have had the following impact

- The funding and evaluation process in instituting two types of CoEs has given long-term public support for developing research capacities in high technology and emerging areas of science and technology.
- The schemes have achieved international recognition of staff and internationally competitive research.
- The Inter University Centres have maintained high standards in building research capacities through professionalisation.
- The schemes have strengthened the infrastructure in universities and CoEs, enabling the academic community to improve their research quality and publications.
- CoEs have improved the quality of training and helped build skills.
- CoEs have developed leadership in some specialist areas of science and technology.
- CoEs in various sectors have resulted in significant improvements in two-way partnerships and collaborations.

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Acronyms and abbreviations

AICTE All India Council for Technical Education
BERD Business expenditure on research and development
CAS Centre for Advanced Studies
CPE Colleges with Potential for Excellence
CPEPA Centres with Potential for Excellence in Particular Areas
DBT Department of Biotechnology
DOT Department of Telecommunications
DRDO Defence Research and Development Organisation
DRS Departments for Research Support
DSA Department of Special Assistance
DST Department of Science and Technology
GMRT Giant Metre-Wave Radio Telescope ?
HEI Higher education institution
ICT Information communications technology
IHERD Innovation, Higher Education and Research for Development
IIM Indian Institutes of Management
IISc Indian Institute of Science
IIT Indian Institutes of Technology
INR Indian Rupee
IPR Intellectual property rights
IUAC Inter-University Accelerator Centre
IUCAA Inter-University Centre for Astronomy and Astrophysics
MUD Ministry of Urban Development
NAAC National Assessment and Accreditation Council
PPP Public-private partnership
PRS Public research system
PURSE Promotion of University Research and Scientific Excellence
S&T Science & technology
GDP Gross domestic product
GERD Gross domestic expenditures on R&D
TNC Transnational corporation
TOE Telecommunications Centres of Excellence
UGC University Grants Commission
UPE Universities with Potential for Excellence

1. Background

Exploring contemporary policies towards excellence in science and technology (S&T) research in India invariably draws attention to the historical background. It is more than 150 years since the modern universities came into being. The first universities were established Calcutta, Bombay and Madras in 1857, during the colonial era. The precursors to the modern full-time research institutions go back more than 225 years with the beginning of the Asiatic Society of Bengal, established in 1784. By the late 19th century this had been followed by nearly a dozen scientific research and survey-based institutions such as the Trigonometrical Survey of India, the Geological Survey of India and the Meteorological Department. India is perhaps unique amongst developing countries in having established a distinct science identity as early as the 20th century. This identity reflected both the institutionalisation and professionalisation of science with advances in scientific research in chemistry, biology, mathematics, astronomy, literature and physics. India can boast of two Nobel laureates in the last of these two fields, namely, Rabindranath Tagore (awarded in 1913) and C.V. Raman (in 1931).

This initial phase of Indian scientific development, up until the 1950s, not only led to the emergence of an Indian science community but also a few institutional locales of scientific excellence. Some of India's eminent S&T institutions originated during this period. The Indian Association for the Cultivation of Science (1876) transformed into a full-fledged research institute with C.V. Raman joining it in 1907. The Indian Institute of Science (1909), Bose Research Institute (1917), Raman Research Institute (1938), Tata Institute of Fundamental Research (1945) and Calcutta College of Science (1918) are all institutes carrying out frontier research in S&T. Two important science agencies which also had their origins in the 1950s are the Atomic Energy Commission and the Indian Space Research Organisation.

Historically much of the S&T efforts, both in terms of locus of research and funding, has been dominated by the government science agencies. India had over 500 universities in 2012 but they accounted for only marginal amounts of its gross domestic expenditure on research and development (GERD). India's GERD as a proportion of gross domestic product (GDP) progressed gradually from 0.69% in 1995-96 to 0.81% in 1999-2000; to 0.88% in 2006 to 1% in 2008-10. A significant majority, around 68%, comes from government sources. Within this, the university sector only accounts for 6-7% of total GERD. Private R&D accounts for 30%, but the business enterprise or private R&D has only formed a significant part of total expenditure since 2005. The priority of much of the public investment in R&D over the last decade and a half has been the strengthening of the public R&D system including national labs and universities. Here again, the university sector has been quite marginalised in terms of R&D in higher education.

2. Policy context

India's national system of innovation

India's national innovation system consists of:

a) Public research system (PRS). This comprises national laboratories under a dozen science and technology agencies including space, atomic energy, agriculture and industrial research, as well as in-house R&D laboratories in large public-sector enterprises in steel, fertilisers, railways, power, transport and aviation, chemicals, petroleum and energy. The other segment of the PRS is the higher educational institutions and university system. With public research accounting for 68% of GERD, the PRS has historically dominated R&D in the country.

b) Higher educational institutions (HEIs). There are over 500 universities with 26 000 affiliated colleges, making HEIs an important part of the PRS. Much of the recent dynamism witnessed in the knowledge-based and high-technology sectors of Indian economy is the result of human resources, skills and the institutional base created by the higher educational sector. However, direct R&D in HEIs in India is weak. HEIs account for a mere 14% of R&D personnel compared with 55% of total R&D personnel of the country employed in non-HEIs in the public research institutions. The rest of the personnel are in the private business enterprises

c) Private business enterprises and transnational corporations (TNCs). Businesses are the second major actor in the Indian innovation system. In recent years the business enterprise sector has assumed considerable importance, achieving a global competitive edge in pharmaceuticals, automotive technology, software, telecommunications and biotechnology. In 1990-91 private business expenditure on research and development (BERD) accounted for 13.8% of GERD, increasing to 20.3% in 2001-02, and 23% in 2006 before reaching 30% in 2010. *The Steering Committee Report of the Planning Commission for the 12th Plan (2012-2017)*[1] and the *2011 Report of the National Innovation Council,*[2] an advisory body to the Prime Minister, have underlined the importance of increasing the proportion of business expenditure in GERD.

d) Public policies on science and technology. The government in 2003, announced a new national science, technology and innovation policy (STIP 2013). However, in the last decade the importance of individual sector-based science, technology and innovation policies have come into sharp focus and importance such as the new Telecom Policy, 2012; national policy on electronics, 2012 or national manufacturing policy 2011.

e) Non-governmental research institutions aided by both public and private sources. This sector plays a very important role in representing civil society. Over the last few years it has 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. It is involved in research into the environment, ecology, energy, rural development, women and gender, grass-root innovations, and small technology research including cottage- and micro-enterprises.

The S&T Steering Committee of the Planning Commission, which is the nodal agency giving direction to various sectors, has set the ambitious goal of having national R&D reach 2% of GDP. It also seeks a paradigm change in the orientation of science and technology policies: away from input-oriented policy mechanisms towards a focus on the demand and diffusion end of the spectrum.

The government has a renewed policy focus to solicit the participation of the business enterprise sector through public-private partnerships (PPPs) in almost all sectors of the economy including the social and S&T sectors. The business enterprise sector has largely contributed to meeting the human resource demands for the technical, engineering, management and medical sciences in the last decade. This is likely to expand through PPPs.

India is among the top S&T producers of science publications in the world but is lagging behind China. The quality of India's research output fares better in terms of journal citations and other quantitative measures when compared to China.

Indian universities are yet to wake up to the emerging world of innovation involving "triple helix" partnerships, between university, industry and government. By and large, universities interact with industry through the traditional mode of consultancy and sponsorship. With the exception of the Indian Institutes of Technology (IITs) and Indian Institutes of Management (IIMs), universities have yet to accept the culture of innovation as an important part of their domain along with teaching and research.

Indian CoE schemes under the PRS

The use of Centres of Excellence as a strategy to advance scientific research and build certain scientific and technology capacities in Indian science and technology is a recent development. As noted above, even though the country institutionalised and promoted several specialised institutions in various frontier areas of S&T early on, such as the Indian Association of Cultivation of Science,[3] Calcutta; Tata Institute of Fundamental Research,[4] Bombay; and the Indian Institute of Science,[5] Bangalore, CoE as a policy mechanism only emerged about two decades ago. India's PRS consists mainly of the science agencies under the Ministry of Science and Technology and other ministries, the universities under the University Grants Commission[6] (UGC), and HEIs under the All India Council for Technical Education[7] (AICTE). India's CoE schemes fall under the science agencies under various ministries; and the universities under the UGC.

3. CoE schemes oriented to science advancement in universities

The Indian university system under the UGC may be said to be the first actor of the NIS, which initiated the CoE scheme in the early 1980s. There are three types of CoE schemes or programmes operating in Indian universities. The UGC administers two of them: Inter-University centres; and the Universities with Potential for Excellence and Colleges with Potential for Excellence and the Department of Science and Technology (DST) initiated the third, a scheme called Promotion of University Research and Scientific Excellence (PURSE). Much of the information and data on COE scheme for UGC is drawn from the relevant website (http://www.ugc.ac.in/).

Table 1. CoEs in universities and their areas of specialisation[8]

Administering agency	Scheme (Year of establishment)	Areas or fields of specialisation/purpose
UGC	Inter-University Accelerator Centre (1984)	Accelerator-based research in nuclear sciences
UGC	Inter-University Centre for Astronomy and Astrophysics, (1988)	Advancing the fields of astronomy and astrophysics
UGC	Inter-University Centre for International Relations, (2010)	Humanities and social sciences
UGC	Universities with Potential for Excellence (UPE) (1998-2012) 46 universities: 5 in 1998-2002, 16 in 2002-07, 25 in 2007-12.	Frontier areas in biological, chemical, telecommunications, physical and engineering sciences. Examples include green technology, mobile computing, nanoscience; herbal science, biotechnology, genetics and genomics.
UGC	Colleges with Potential for Excellence (CPE) 2002-2012.	97 colleges covering all areas of social and natural sciences, improving teaching standards, supporting research, and enhancing quality and infrastructure.
UGC	Centres with Potential for Excellence in a Particular Area (CPEPA) (2007) 12 centres in universities 2007-12.	Basic and applied research in frontier areas
DST	Promotion of University Research and Scientific Excellence (PURSE) (2009) 14 universities in 2009-10, 30 in 2010-11.	Covering all areas of social and natural sciences, improving teaching standards, supporting research, and enhancing quality and infrastructure. Value-added proactive measures for enhancing research capacity.

	30 universities in 2010-11	

Strategic orientation

As shown in the above table, there are three types of schemes to promote the concept of excellence in the Indian university and academic institutions. The UGC was the first organisation to institutionalise and promote the notion of excellence in the academic institutional sphere.

Inter University Centres of Excellence

The first UGC scheme institutionalised the concept of excellence in specialised areas and frontier fields of research in the form of Inter University Centres. The first such centre was the Inter-University Accelerator Centre[9] (IUAC) established in 1984 at New Delhi. The main objective of this centre is the promotion of nuclear science and accelerator-based research. These centres provide common facilities for research and various specialised services and programmes to universities but not restricted to them alone. The centre mainly promotes experimental science.

The second Inter University Centre is the Inter-University Centre for Astronomy and Astrophysics[10] (IUCAA) at Pune, established in 1988. This centre aims to be a centre of excellence within the university sector for teaching, research and development of astronomy, physics and astrophysics, as its name suggests. It has active research groups in fields such as classical and quantum gravity, cosmology, gravitational waves, radio astronomy, solar system physics and instrumentation.

The third is the Inter-University Centre for International Studies in the social sciences and international studies. Its goal is to promote specialised research in education, economics, world trade, intellectual property rights (IPR), diplomacy, human rights, life skills, conflict management and allied arts, and human sciences.

All three centres were selected to promote basic research and advance knowledge in specialised areas. The IUCAA, which operates in astronomy and astrophysics, undertakes pure and fundamental research along with basic research. All the Inter University Centres perform teaching, research and advancement of knowledge activities in their respective fields of operation. The IUCAA is also involved in the popularisation of the subject of astronomy both in the society and educational institutions.

Universities and Colleges with Potential for Excellence

Over the last six decades, HEIs, ranging from universities, affiliated colleges and specialised technical institutions such as IITs and IIMs, have grown into an important sector of India's national innovation system. There are some 500 universities and over 18 000 colleges with a gross enrolment ratio of 16. In absolute terms this makes India's HEI sector one of the largest in the world. From the 9th Plan period (1998-2002), the UGC introduced a scheme to encourage and

promote measures to improve quality and excellence in teaching and research in Indian universities and colleges. During this period the UGC introduced two schemes, Universities with Potential for Excellence[11] (UPE) and Colleges with Potential for Excellence[12] (CPE). During the 10th Plan period (2002-07), the UGC introduced a third scheme called Centres with Potential for Excellence in Particular Areas[13] (CPEPA), while continuing with the other two. Universities, colleges and centres in various institutions are selected by the UGC on the basis of certain performance merit criteria. As shown in Table 1, 46 universities and 97 colleges were given special grants and support under the respective schemes from 1998-2012. Some of the universities selected as UPEs in the 10th Plan were given further support in the 11th Plan under the CPEPA scheme.

Under the UPE scheme universities were required to take up research and other academic activities in one or more interdisciplinary or multidisciplinary areas of research ranging from physical, chemical, biological or social sciences and the humanities.

Under the CPE scheme, colleges located in less-developed regions of the country and new colleges (under the "Young Colleges" scheme), were selected for support. The support extended was for introducing innovative changes in curriculum design, teaching, computer connectivity, Internet connectivity, improving the quality of teaching and so on. The scheme accorded a certain degree of autonomy to selected colleges to enable them to introduce various innovative changes.

The CPEPA scheme was designed as a subsidiary scheme to extend the period of support to UPE universities. Closely linked to the UPE scheme, UGC devised three more windows of support to both UPE-based universities and others. These are Departments for Research Support (DRS), the Department of Special Assistance (DSA) and the Centre for Advanced Studies (CAS). All university and college-based departments seeking support for faculty, introduction of new courses and research support compete for these grants.

Promotion of University Research and Scientific Excellence (PURSE)[14]

The Department of Science and Technology (DST) administers the third scheme called PURSE. Based on the research contribution of universities measured through the SCOPUS database and h-index, [15]DST initiated the PURSE scheme from 2009-10 to provide substantive R&D grants to promote scientific research. DST supported 14 universities in 2009-10 and 30 more were selected for PURSE support in 2010-11.

Funding and evaluation mechanisms

The funding and evaluation of the three broad types of CoE schemes vary according to their different institutional and organisational contexts.

Inter University Centres

The three Inter University Centres established under the UGC are jointly funded from grants from the UGC, the Ministry of Human Resource and Development, the DST and some marginal funding from the State governments where the centres are located. The centres are located in Pune, New Delhi and Hyderabad and operate in the same way as other national laboratories.

The initiative to apply to become an Inter-University Centre originates with elite scientists or faculty members, who have generally achieved international recognition. However, the decision to establish is made by the UGC governing body in consultation with the Education Ministry and the Ministry of Science and Technology.

Universities with Potential for Excellence

Under the UPE scheme, prior to the 11th Plan (2007-2012), each university was provided with INR 300 million for a planning period of five years (approximately EUR 3.9 million). Of this amount, 30% was to be spent on the focus area and 70% on holistic development of the university. During the 11th Plan period, the ceiling of assistance was raised to INR 500 million (EUR 6.4 million). The same division of spending applied: 30% on the focus areas and 70% on holistic development of the university.

The selection and evaluation process begins with the UGC issuing calls for the scheme from the Indian universities. On receipt of proposals a committee shortlists universities. Expert Evaluation Committees visit the universities and submit the reports to UGC. Shortlisted universities are called to give a presentation by their Vice Chancellor before the Standing Committee on UPE for final selection.. The Expert Evaluation Committees use the following scoring scheme developed by the working group on UPE for submitting the evaluation reports:

– 40% for data provided by the university in the application
– 40% given by the Expert Evaluation Committee after visiting the university
– 20% awarded by the Standing Committee after a presentation made by the Vice Chancellor.

Colleges with Potential for Excellence

The CPE Scheme was introduced in the 10th Plan (2002-07) to financially support colleges to improve their academic infrastructure; adopt innovations in teaching, learning and evaluation and to introduce a flexible approach in the selection of courses at the degree level. A CPE college acts as a role model for other colleges in their area of operation. The objective of the scheme is to help selected colleges achieve excellence in teaching activity and initiate a research culture. All colleges are evaluated by the National Assessment and Accreditation Council[16] (NAAC) of the UGC through merit-based indicators. These indicators form the initial basis to select or shortlist the universities and colleges which put in applications for the various excellence schemes. These schemes are not

open but UGC issues calls for applications particularly during the beginning of the every Five Year Plan periods or from time to time during the five year plan period.

Under the 10th Plan a non-autonomous and non-NAAC accredited college can be given assistance of up to INR 3.5 million (approximately EUR 45 000). Colleges which are autonomous but accredited, or accredited but not autonomous can be given assistance up to INR 60 million (EUR 770 000). Colleges which are both autonomous and accredited can be given assistance of up to INR 1 000 million (EUR 12.8 million).

Under the 11th Plan (2007-2012) the amount of support was increased. For accredited but not autonomous colleges the assistance was raised to INR 10 million. For accredited and autonomous college the assistance was raised to INR 1 500 million (EUR 19.3 million).

Governance

Inter University Centres operate as autonomous national laboratories governed by a top-level council and a governing body. There is a Scientific Advisory Body to advise on the structure and goal direction of academic and research programmes of the centre. The executive authority however is vested in the director of the Inter University Centre.

The UGC based schemes, (UPE, CPE and CPEPA) are administered by the UGC and there are special evaluation and monitoring committees constituted to govern these schemes. The monitoring of UPEs is done by the UGC and uses both internal and external evaluation. The Monitoring Committee visits each one of the UPE universities to monitor the progress of work done during the previous year or years. At the end of the five-year period, an Expert Committee evaluates progress, followed by a further visit from the Monitoring Committee. In addition to the external peer group evaluation, the Vice Chancellor of the university carries out continuous evaluation with the help of the Steering Committee. A similar process is carried out in the case of CPEs, the only difference being that CPEs are mainly supported to induce improvements in the quality of teaching and colleges are given a certain amount of autonomy to experiment and introduce innovations in the curricula, teaching methods etc , to see that the standards are maintained.

Capacity building and impact

Research capacities

The purpose of the Inter University Centres is to undertake research and enhance national research capacities in some areas of national importance. These centres are meant to advance research and enrich teaching. Among these centres, IUCAA enjoys a special status and recognition as it operates in the field of astronomy and astrophysics. It hosts national facilities such as the Giant Metrewave Radio Telescope (GMRT), the Exploratorium, the Virtual Observatory which allows users to access raw observational data along with advanced software, the Girawali Observatory catering to astronomers and common equipment to popularise astronomy. It has a 10% stake in the Large

Telescope Project, which allows Indian astronomers to have access to Giant Magellan Telescope, the Thirty Meter Telescope and the European Extremely Large Telescope. In collaboration with various colleges, IUCAA imparts training and disseminates knowledge on astronomy and astrophysics using the research findings generated at the main laboratory site. More than 300 researchers and visiting fellows work at the IUCAA. Several of its leading scientists such as Jayant Narlikar, Govind Swarup, Arvind Gupa, Varun Sahani, and Arvind Paranjpye have achieved international recognition. One of the objectives and aims of the centres is to gain international visibility through research excellence and the advancement of knowledge at the frontiers. International benchmarking is done to evaluate the research work at these centres.

Similarly, the Inter University Accelerator Centre has established sophisticated accelerator systems and experimental facilities in projects involving several universities for internationally competitive research in the areas of nuclear physics, materials science, atomic physics, radiation biology, radiation physics and accelerator mass spectrometry.

Inter University Centres have maintained high standards in building research capacities through professionalisation. The centres have placed great importance on quality research contributions and the goal of advancing science when recruiting professionals. Overall, the role of scientific leadership in both the organisation of research and the recruitment of new researchers has been a crucial and defining factor in sustaining the eminence of the Inter University Centres.

The UPE and CPE schemes were introduced to create funding mechanisms for improving the quality of research and teaching and modernising infrastructure to enable universities to attain the benchmarks of excellence in academic institutions. Whilst the focus in UPE is both in teaching and research, the main objective in CPE is to enrich quality of teaching at the undergraduate and postgraduate levels.

Technology and innovation and socio-economic development

The university CoE schemes operating are not specifically directed or constituted to promote technological innovation, university-industry relations or transfer of knowledge to create new firms. Most of the UPE schemes are meant to strengthen the research quality, excellence and visibility in the international sphere of the science community. For CPE schemes the purpose is to improve infrastructure and improve teaching standards.

Infrastructure

The UPE scheme has strengthened the infrastructure in universities, enabling the academic community in UPE-supported institutions to improve their research quality and publications. India can today boast of having state-of-the-art scientific equipment in some niche areas such as optical and radio astronomy, gravitational waves, solar system physics and astrophysics, with world-class observatories mainly due to UGC Inter University centres in specialised areas of research. The telescope at Girawali Observatory built near Pune city has a primary mirror of diameter 2m, f/3 and

a secondary of 60 cm, f/10. Faint object spectrograph and camera (IFOSC) is the main instrument available on the telescope's direct Cassegrain port currently. IUCAA has gained international visibility as an important science institution in astronomy and astrophysics.

The Inter-University Accelerator Centre has a running Pelletron, a tandem van de graaf type accelerator. The pelletron has been operating since July 1991. Another facility is the superconducting linear accelerator. The accelerating structure for the superconducting linac booster for the 15 UD Pelletron at IUAC is a Niobium Quarter Wave Resonator, designed and fabricated as a joint collaboration between IUAC and Argone National Laboratory (ANL), USA. Initial resonators required for the first linac module were fabricated at ANL. For the fabrication of resonators required for future modules a Superconducting Resonator Fabrication Facility has been set up at IUAC. A three-quarter wave resonator (QWR) has been fabricated and fifteen more resonators for the second and third linac modules are in the advanced stage of completion.

A project for indigenous fabrication of resonators (IFR) has been started. All the required facilities such as Electron Beam Welding Machine, Surface Preparation Laboratory and High Vacuum Furnace has been operational. The Low Energy Ion Beam Facility (LEIBF) at the Inter-University Accelerator Centre provides multiply charged ion beams at a wide range of energies (a few keV to about an MeV) for experiments in Atomic, Molecular and material sciences.

While the UPE schemes have been directed to develop world-class facilities for research to promote excellence in the university sector to gain international visibility and recognition in science, CPE schemes are meant to improve the infrastructure in select colleges at the national level. This is because additional funding is made available compared to other similar educational and research units/colleges.

Training

All CoEs in the university sector, particularly Inter University Centres have placed emphasis on professionalising research, including publishing research in high quality journals, peer reviews and research contacts with leading-edge science centres in the relevant field, and quality of research in both research and training.

IUCAA's activities fall under two broad programmes: a) core academic programmes; and b) visitor academic programmes. Core academic programmes include basic research, promotion of PhDs and advanced research, specialised workshops and the creation of specialised centres. The visitor academic programme includes the visitor and associate programme which conducts refresher courses for teachers and helps the promotion and growth of astronomy and astrophysics at the Indian universities and colleges. IUCAA has joined with colleges such as Ferguson College, in Pune, to disseminate knowledge and astronomy and develop interest among students. Eminent scientists such as Dr Narlikar frequently deliver lectures and have interactive sessions with students on astronomy.

Similarly, the IUAC runs science masters and PhD programmes including its summer training programmes which are given high importance. Both the IUCAA and the IUAC have given professional recognition to high-quality research undertaken in their respective domains. Both have developed a wide network of relationships with relevant research groups and institutions worldwide. The activities in these centres concern both basic and applied research and a number of research partnerships have evolved.

Similarly the PURSE scheme, which covers over 44 universities, promotes PhD training in all branches of science and technology.

4. COE Schemes oriented to research and innovation in science agencies

Table 2. CoE Schemes in science agencies[17]

Government agency	Type of CoE	Main focus	Number CoEs
Department of Biotechnology (DBT)[18]	Physical and virtual centres	• Develop infrastructure through thematic centre with interdisciplinary focus	9 centres already established 2007-11 16 more proposals for centres in 2012
Ministry of Urban Development[19]	Centres located at different institutions	• To meet the complex urban problems and development	9 centres of excellence in various institutions
Defence Research and Development Organisation Ministry of Defence[20]	Centres of Excellence	• Basic and applied research	5 centres in various institutions
Department of Telecommunications[21]	Telecommunications Centres of Excellence	• To meet the technical and professional demands of expanding telecommunications industry in India	7 centres established
Government departments in Information and Communication Telecommunications, urban development etc.	Creating centres of excellence in specialised institutes (IITs, IIMs, IISc) 2002-12	• IIT Kaharagpur: Vodafone –IIT centre of excellence in telecommunications; Microsoft centre of excellence in intellectual property. • IIT Delhi: Airtel –IIT CoEs in telecommunications & urban development. • IIT Madras: CoEs in intelligent systems,	15 centres established

		urban development, automation and telecommunications. • IIT Kanpur: telecommunications. • IIT Bombay and Indian Institute of Science, Bangalore: CoEs in nanoelectronics, urban development and telecommunications • IIT Roorke: CoEs in disaster mitigation and management, and urban development. • IIT Guhati: urban development. • Administrative Staff College of India: urban development. • IIM: telecommunications. • IISc: telecommunications.	

Strategic orientation

As shown in Table 2, there are five government science agencies dealing with biotechnology, telecommunications, urban development, information communications technology (ICT), and defence. Together they had established 45 CoEs by 2012, with 16 more being implemented in biotechnology. Though most of these CoEs are established in specialised academic institutions such as Indian Institutes of Technology and other national laboratories, their objective is to mainly promote research and innovation. This is in contrast to CoEs in universities, which have the objective of advancing scientific research. Given the nature of the research areas they cover, falling mainly in new technologies such as biotechnology, ICT and telecommunications, the major aim of these centres is to establish high levels of technological competence and research capacities for creating innovation potential. The other important aim is converting research into technological products and processes through partnerships between universities and industry. For example, the

fields of ICT and telecommunications require a range of engineering and networking skills to aid modernisation of the industry and their implementation. Hence, the science agencies have promoted an agenda of learning sophisticated skills, technological networking and servicing the industry to upgrade their skills through the CoEs. Let us briefly explore various CoE programmes in science agencies.

Department of Biotechnology (DBT) CoEs

The DBT has initiated a programme to develop and enhance research capacity in areas of biotechnology through the establishment of CoEs. The DBT provides flexible support a) to expand and develop faculty research capability; and b) to enhance research infrastructure. Centres of Excellence can have a specific thematic focus but must have a multidisciplinary approach to research within that theme. The DBT promotes three types of CoEs: a) basic biology CoEs which focus on new opportunities in emerging fields; b) centres for science, engineering and technology that promotes interaction between engineering, physical sciences, biology, medicine, agriculture or forestry; and c) translational centres directed towards innovation in the areas of medicine, agriculture, environment, animal and food biotechnology.

Department of Telecommunications (DOT) CoEs

The idea of Telecommunications Centres of Excellence (TOE) emerged with the realisation by government and the telecommunications industry that a high growth trajectory of telecommunications (in 2012 India had some 960 million mobile users) was essential for the overall progress of the country. The government realised that efficient and professional services in communications could not be accomplished without promoting excellence in research, development and innovation for national needs. The TOE initiative came into existence with the signing of tripartite Memoranda of Understanding between the Department of Telecommunications, Government of India, participating institutes and the sponsors from the industry. The TOEs, set up in public-private partnership (PPP) mode, exemplify the sort of partnerships between industry and academia needed for the sustained growth and progress of the country.

Ministry of Urban Development (MUD) CoEs

In March 2009 the Ministry of Urban Development established nine CoEs on urban development under its scheme for capacity building for urban local bodies. The CoEs were established in leading academic and research organisations like IITs and IIMs across the country with the aim of strengthening capacity building measures, and promoting awareness, research and training in priority areas.

Defence Research and Development Organisation (DRDO) CoEs

DRDO is a science agency with more than 50 laboratories. These are deeply engaged in evolving research and development capacities in defence technologies covering various disciplines, such as aeronautics, armaments, electronics, combat vehicles, engineering systems, instrumentation, missiles, advanced computing and simulation, special materials, naval systems, life sciences, training, information systems, and agriculture. There were over 5 000 scientists and approximately 25 000 other scientific, technical and supporting personnel working in the DRDO in 2012. Several major projects for the development of missiles, armaments, light combat aircrafts, radars, electronic warfare systems etc. are currently under development and significant achievements have already been made in several such technologies. DRDO has already established two CoEs: a) high-energy materials CoE in collaboration with the University of Hyderabad; and b) a life sciences CoE in collaboration with Barathiar University, Tamil Nadu. It is currently working to establish three more in the areas of polymer science and polymer electronics, nanotechnology and nano-optoelectronic devices, and microwaves and matter (stealth).

Funding and evaluation mechanisms

All the CoEs in the various science agencies are established and funded with the intention of attaining research excellence in the long term. It is for this reason that most CoEs have a life of at least a decade, on an extendable five-year plan basis.

While the DBT devoted INR 160 million (approximately EUR 2.6 million) to CoEs in 2011-12, it earmarked INR 500 million (EUR 6.4 million) for CoEs for the five years during the 11th Plan period (2007-12). The telecoms CoEs operate through PPPs with the government investing 10%, while the business enterprise partners contribute the remaining 90%. The participating institutes provide infrastructure, human resources and R&D space. These institutions in turn obtain project-based funding for the CoE from regular government schemes.

Science agencies CoEs are evaluated not just from the perspective of their scientific and research excellence but also from the perspective of developing innovation capacities for commercialisation of research. This is particularly relevant for CoEs under the DBT. The telecoms CoEs are evaluated from the perspective of their contribution to the modernisation of skills and dissemination of best practices of telecommunications networks in the industry.

All centres are also evaluated on the basis of their contribution to improving efficiency measures in communication. Research excellence capacities are measured by research contributions to quality journals.

Governance

All of the different science agencies CoEs have governing structures that reflect their parent ministries. Examples of two sectors are given below but most have a somewhat similar structure of governance and considerable autonomy in decision making, except the CoE under the DRDO, which is in the strategic sector. The DRDO CoEs which are linked to the development of technological and innovation capacities in strategic military oriented goals work under the command of the Ministry of Defence.

DOT Telecommunications: each CoE is governed by a governing council led by a senior bureaucrat (at the level of the secretary to the government of India) from the Ministry for Strategic Planning. Each institution and its partnering business enterprise are represented on the governing council. An autonomous core group at each centre addresses national and local issues. The centres are managed by a seven-member core group under the co-chairmanship of the head of the host institute and the sponsor or business enterprise. There is also a co-ordinating centre which co-ordinates activities among all the different CoEs in the country. Industry representatives are given membership in the co-ordinating centre.

DBT Biotechnology: a committee led by the head of DBT, ministry representatives and other eminent members governs and selects CoEs. Award decisions are based on scientific and technical merit as determined by peer review and the recommendations of the programme advisory committee. The decision to award a CoE takes into account the objective of enhancing basic research capability in medical school systems, translational capacity in basic science institutions and the availability of funds. Both excellence in technology development and science will be considered in the proposals for CoEs. Proposals with merit that do not qualify for support as a CoE, may be considered for "Programme Support".

Capacity building and impact

Research capacities

All of the CoEs are structured and organised to build capacity in research and innovation. In some niche areas of science and technology such as biotechnology, telecommunications, defence research and development, and urban development they are developing leadership. For instance, the urban development CoEs seek to address urban development issues at national, state and local levels and are meant to support state and local government in key areas of urban development and transportation. There is a CoE on intelligent transport systems at the IIT Madras. Similarly, there is a CoE on disaster management and mitigation at IIT Roorkee whose objective is also to develop capacities in sustainable designs, green ratings for buildings and energy-saving measures in the Indian context.

The main objective of the DBT CoE scheme is to develop research and innovation capacities at the intersection of science, engineering, biology, medicine and agriculture. for example there are CoEs designed to contribute capacity building in research and innovation in a) silkworms for Baculovirus resistance and immune systems; b) virtual centres where a group of institutions could co-operate and enhance their research capacities in antigens that can be used as vaccines in tuberculosis and identification of genes involved in pathogenesis of mycobacterium tuberculosis; c) anti-malarial and anti-tubercular leads for therapeutics; d) effective and efficient diversity array technology platforms for enhancing the efficiency of basic research; and e) the molecular basis of heterosis by microarray-based transcriptome profiting of Paddy hybrid.

Resource creation

The infrastructure for CoEs in telecommunications, urban development and biotechnology is created in the host institutes, mainly the IITs and universities. The PPP model is used to create resources for research and innovation. The concept and institutionalisation of CoEs have been a key factor behind the creation of infrastructure and research resources in various niche areas of CoE operation.

Research collaboraton

CoEs in various sectors have given a big boost to two-way partnerships and collaborations. In sectors such as telecommunications, urban development and defence sectors, where the main sponsors of the CoEs have been the relevant ministries, this initiative has led to "triple helix" type partnerships between government, research institutes and business enterprises. On the other hand, in sectors such as biotechnology, the initiative has mainly led to research-industry partnerships. In some cases, such as Centre for Nanoelectronics at IIT Bombay, more than two research institutes, business enterprise and government agencies are involved. These types of partnerships are evident from the joint publications and research output. With the exception of the defence sector, all transactions and collaborations are open and driven by the objective of attaining excellence in research and innovation.

Socio-economic and development

One of the major objectives of CoEs in the urban development, biotechnology and telecommunications sectors has been to contribute to broader social and economic goals, serving society at large. It is too early to assess the impact at this stage.

Training and skills

Training and imparting skills and creating a specialised human resource base are the cornerstone of the CoE strategies in science agencies. All CoEs are engaged in imparting training and specialised

skills, particularly from an interdisciplinary perspective. However, this takes different forms and uses methods in different sectors. for the biotechnology CoEs sponsored by the DBT, involving master and PhD scholars for training and imparting skills is one of the major objectives. Almost all the CoEs established by DBT involve universities and hence integrating masters and PhD scholars in the centres is a natural outcome.

In the case of telecoms CoEs the involvement of the business enterprise sector and training professionals as part of PPP based partnerships is one of the important objectives.

In the case of urban development, the centres have the objective of disseminating expertise and skills to various actors connected with urban issues together with academic masters and PhD training. Training and building capacity for sustainable and green oriented cities go together.

5. Some observations on Indian COE schemes

India has two types of CoE schemes in its national system of innovation. The first is in the university system, geared towards professionalising and advancing science and training in specialised areas of science and technology. The second type is in the science agencies, geared towards research, innovation and specialised services in new technologies and sustainable living. Even though the latter is sponsored by science-oriented ministries, almost all these CoEs are located in specialised academic research institutes such IITs and IISc. Some preliminary observations from our exploration are as follows:

First, the funding and evaluation process in instituting two types of CoEs has given long-term public support for developing research capacities in high technology and emerging areas of science and technology. The Indian S&T system is not investing as much in national R&D compared with industrially advanced countries, and without the CoE schemes it would not have been possible to plan and sustain centres of excellence. Hence, the funding schemes have given this long-term assurance to promote science and technology and developing national research and innovation capacities in some specialist areas.

Second, the governance, recruitment of professionals and evaluation standards followed in the CoE reflect best practice in science excellence. They are sustained by quality research output and peer evaluation.

Third, an important factor for CoEs in the university system has been the role of leadership, particularly among the scientific elite who have established professional recognition in the world of science. The most important feature of this leadership in the Inter University Centres has been the commitment to advancing science and specific institutional efforts invested in giving a distinct identity to Indian science within the international sphere of sciences. In a somewhat similar way, the role of technocratic leadership in the science ministries is seen as important for the science agency CoEs. The ability of the leadership to foresee what sub-disciplines and interdisciplinary areas of research are important to meet the demands of research and innovation for an industrialising and growing economy is seen as an important factor.

Fourth, the process of research capacity, networking and collaboration, funding and evaluation of CoEs need to be contextually defined. For instance, what is appropriate for an area such as radio astronomy may not be appropriate when we consider areas such as urban development or even telecommunications.

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[4] Tata Institute of Fundamental Research: www.tifr.res.in/index.php/en/

[5] Indian Institute of Science: www.iisc.ernet.in/
[6] University Grants Commission: www.ugc.ac.in/
[7] All India Council for Technical Education www.aicte-india.org/
[8] Information in the table is drawn from relevant websites and telephonic conversation held with some officials of the University Grants Commission.
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