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MAPPING THE INDIAN NANOTECHNOLOGY INNOVATION SYSTEM

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Abstract

Purpose: The present paper aims to map out the Indian nanotechnology innovation system. An attempt is made to identify the dominant actors, collaborative pattern and analyse the role of and interactions between the actors and institutions.

Design/methodology/approach: A combination of frameworks such as national, sectoral and international system of innovation is used to include all possible actors and institutions involved. A scientometric analysis is also carried out.

Findings: Despite a series of government interventions discernible in various programmes since the 1980s, nanotechnology-based industries are yet to emerge as a dominant sector. The health sector has emerged as one of the major contributors. There are many other challenges of safety and standards, socioeconomic, ethical and environmental concerns. Academic R&D labs are active in technology transfer.

Originality/value: A scant literature is available for this sector in India and especially from the international innovation system framework to analyse the socioeconomic and risk governance issues.

Keywords: India, Innovation systems, International collaboration, Nanotechnology

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INTRODUCTION

Nanotechnology is both an area of inquiry and application. It finds its application in diverse fields such as agriculture, energy, health, electronics, cosmetics, textiles, water treatment, etc. Across the world, many countries have launched several initiatives in order to tap the enormous potential nanotechnology offers. However, the areas of application might differ in the developed and the developing countries. The importance of RDI (research, development and innovation) in nanotechnology is paramount. This paper attempts to map the Indian nanotechnology innovation system from the systems of innovation framework. The various systems of innovation have been described by many scholars (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Edquist, 1997; Breschi and Malerba, 1997; Asheim and Isaksen, 2002; Desai, 2009). Although there are some scholars who perceive different frameworks, such as national, sectoral, regional and international systems of innovation as competitive, a wider consensus is emerging not to treat these frameworks as contradictory. The present paper will focus on the interactions between the major components of national and international systems of innovation while mapping the Indian nanotechnology innovation system. In the preceding context, the present paper has carried out a scientometric analysis for tracking nanotechnology research in India using a data search strategy developed by Mogoutov and Kahane (2007) and patent analysis of nanotechnology patents filed under International Patent Classification B82 in USPTO by using the inventor's address as India for the period 2000–2012.

MAPPING FROM THE NATIONAL SYSTEM OF INNOVATION FRAMEWORK

Many scholars describing national innovation systems have emphasized the role of actors or the organisations that promote the generation and dissemination of knowledge, as the main sources of innovation (Nelson 1993; Lundvall 1992). A scientometric analysis has revealed that the public universities are the main source of knowledge generation in the area of nanotechnology, followed by government research centres and laboratories (Figure1).

The **actors** that emerge dominant from the analysis are the national-level centres of excellence/central universities (Figure 2), This implies significant funding from the government agencies in promoting basic and applied nanotechnology research in India.

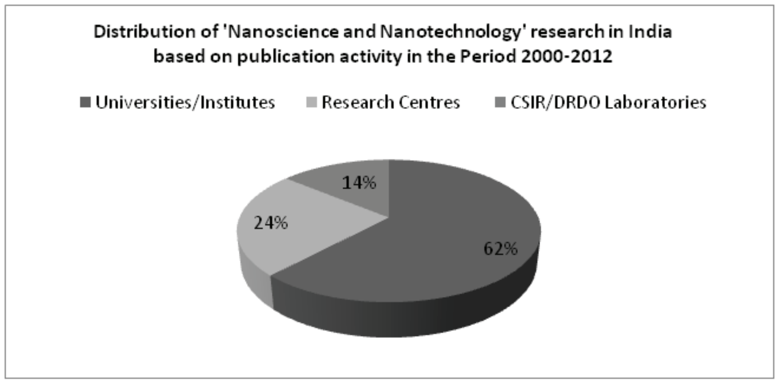


Figure 1 ***Source:*** Thomson Reuter's Web of Science Database, 2013 (analysed by author)

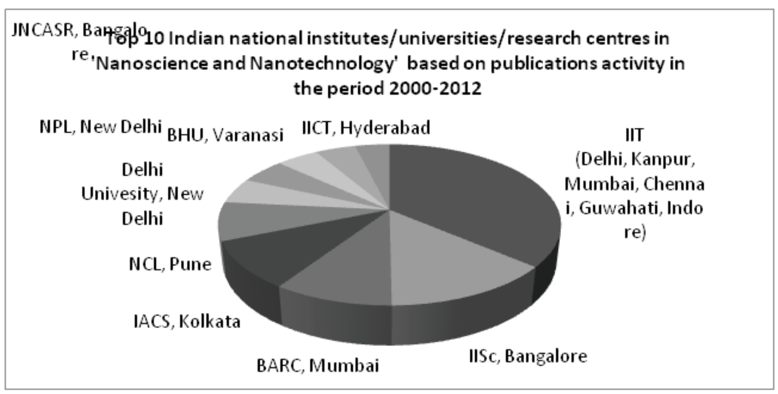
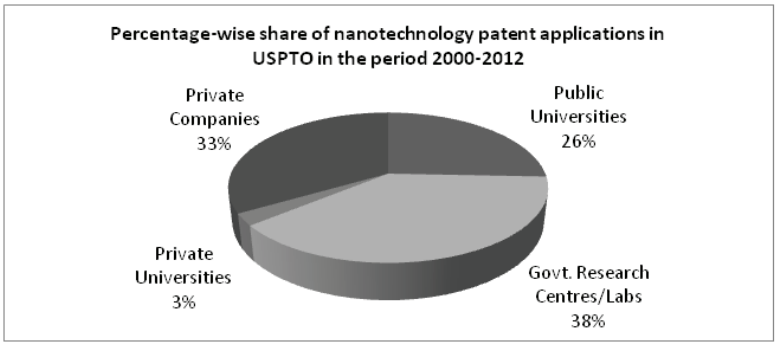


Figure 2 ***Source:*** Thomson Reuter's Web of Science Database, 2013

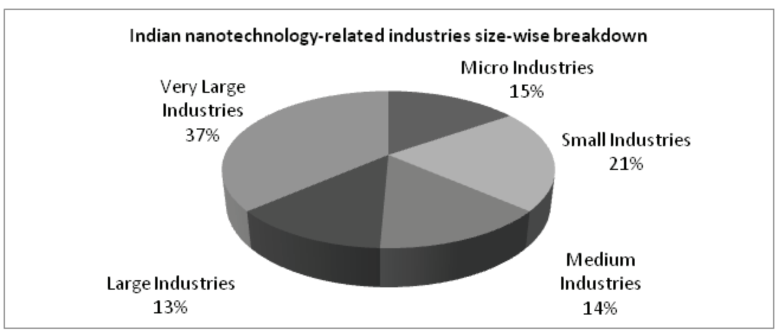
Patent analysis indicates that the government funded research centres/laboratories play a dominant role, followed by the public universities (Figure 3).

Private firms/companies have a one-third share in patent applications in nanotechnology at USPTO. This indicates that as far as nanotechnology-based product/process innovation is concerned, the Indian private industries are not far behind and they could also play a pivotal role in the future. A survey of 300 nanotechnology-related firms/industries in India has revealed that the majority of them are very large firms (employee strength-wise) followed by small-scale industries (Figure 4).



Source: Thomson Innovation Patent Database, 2013 (analysed by author)

Figure 3



Source: Author's own survey analysis, 2013

Figure 4

This demonstrates that the nanotechnology-based product development and commercialisation is dominated by industries that are already well-established entities. These firms have incorporated nanotechnology in their in-house R&D to produce and launch various finished products.

On further analysis, we observe that most of the relatively new firms are micro and small-scale firms and they are mostly into developing intermediary nano-materials, followed by healthcare/medicine related product developments (Figure 5).

Agencies such as central ministries/departments (i.e. Department of Science and Technology, Department of Biotechnology, Department of Atomic Energy, Department of Information Technology) and central

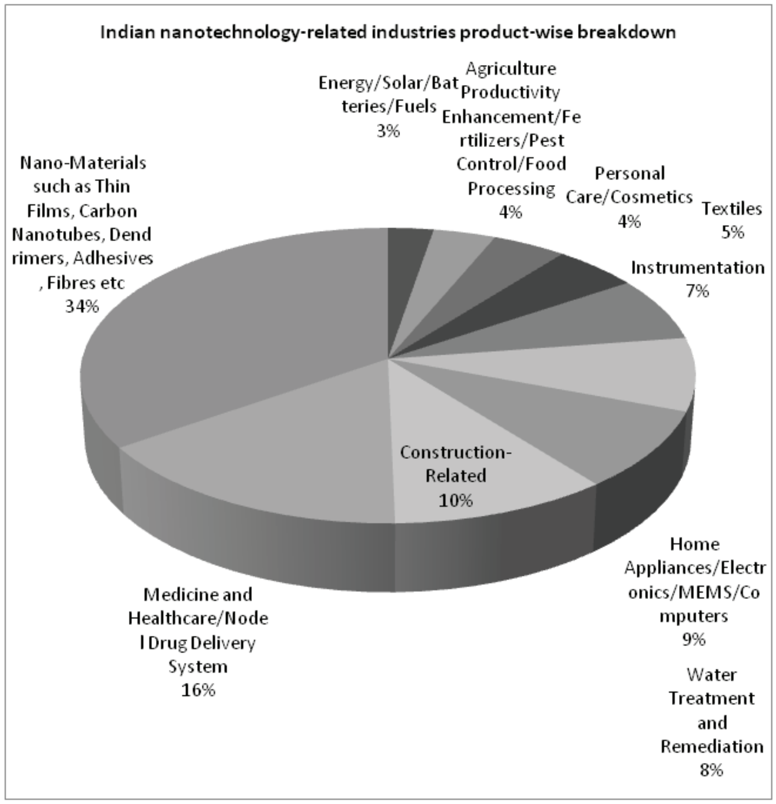


Figure 5 ***Source:*** Author's own survey analysis, 2013

bodies such as the Council for Scientific and Industrial Research (CSIR), Indian Council of Medical Research (ICMR), Defence Research and Development Organisation (DRDO), Indian Space Research Organisation (ISRO), All India Council for Technical Education (AICTE) and University Grants Commission (UGC) provide funding to various universities/research centres all over the country to carry out nanoscience and nanotechnology research projects.

Since the 1980s, there have been various initiatives/schemes launched by the central government for studying emerging technologies and smart materials, such as:

Intensification of Research in High Priority Areas (IRHPAS): A programme launched by DST during 6th Five Year Plan (1980–1985).

TOP 10 COLLBORATING INSITUTES WITH IISc, Bangalore based on Publication Collaboration
JAWAHARLAL NEHRU CTR ADV SCI RES
INDIAN ASSOC CULTIVAT SCI
INDIAN INST TECHNOL
SN BOSE NATL CTR BASIC SCI
BHABHA ATOM RES CTR
DRDO LAB
UNIV MADRAS
UNIV CALCUTTA
CSIR LAB
W BENGAL UNIV TECHNOL

Figure 6

Committee on Emerging Technologies was set up in 1997 to fund research for three years. SERC also initiated a programme on Nanocrystalline material.

National Programme on Smart Materials (NPSM): a five year programme funded for US$ 15 million was launched jointly by five Govt Departments: DRDO, CSIR, DOS, DST and MIT, in the year 2000.

Nano Science and Technology Initiative (NSTI) initiated in 2001 focused on various issues relating to infrastructure development, basic research and application oriented programmes in nanomaterial including drugs / drug delivery/gene targeting and DNA Chips.

Nano Science and Technology Mission (NSTM): The Government of India, in May 2007, approved the launch of a Mission on Nano Science and Technology (Nano Mission) with an allocation of INR 1000 crores for five years (USD 10 Bn).

As far as **Networks and Linkages** at national level are concerned, the paper has analysed the linkage behaviour of a few top ranking institutes/ universities in India. It is observed that they more often tend to build links with other high-performing national universities/government. research laboratories. Figure 6 provides a list of top ten collaborating institutes with the Indian Institute of Science, Bangalore (IISc).

Figure 6 shows that the network and linkage patterns are not confined to any region. It is mostly of a national character, involving research partners from all over the country.

MAPPING FROM THE INTERNATIONAL SYSTEM OF INNOVATION FRAMEWORK

The international innovation system is a relatively new framework. Desai (2009), while discussing international system of innovation and its salient features, argued that with the increasing complexities of emerging technologies like information and communication technologies, biotechnologies and nanotechnologies and the multiplying convergence between them, a greater need is felt for S&T collaboration. Three phenomena of the emergence of these technologies, the international environment movement and globalisation have co-evolved. He further stressed that globalisation has not only introduced fierce competition but there are instances where it has forced competitors to cooperate in these areas. This has further strengthened the linkages between the national and international systems of innovations. There are many components of the international system of innovation, such as inward and outward FDI, migration of knowledge workers, R&D collaborations, institutional linkages, inventor collaborations, export, international institutional factors, etc. Recently, India has emerged as one of the major destinations for the preceding activities (Desai, 2009).

The present paper has attempted to explore such a system from the viewpoint of **international S&T collaborations** in basic and applied research and the **Indian inventor's contribution** in international nanotechnology RDI endeavours.

India collaborates with several countries in this field of nanoscience and nanotechnology research and has attracted collaboration mainly from the most developed countries. This fact is reflected in Figure 7, which provides a list of top 20 collaborators. Most of the top 20 countries that are collaborating with India in this field are developed countries, with the exception of a few examples, including Brazil, China and Saudi Arabia.

TOP 20 COLLABORATING COUNTRIES WITH INDIA based on publication collaboration on Nanoscience and Nanotechnology in the period 2000-2012
USA
JAPAN
GERMANY
SOUTH KOREA
FRANCE
ENGLAND
SINGAPORE
CANADA
ITALY
SAUDI ARABIA
PEOPLES R CHINA
TAIWAN
AUSTRALIA
SWEDEN
SPAIN
PORTUGAL
IRELAND
BRAZIL
SOUTH AFRICA
SWITZERLAND

Source: Thomson Reuter's Web of Science Database, 2013

Figure 7

It is also evident from the patent analysis that Indian inventors were part of the research teams of around 10 countries involved in international patents on nanotechnology. Out of these, the USA had the maximum number of such patents, followed by Germany and the Netherlands (Figure 8).

Countries	No. of patents with Indian inventors
USA	24
Netherlands	4
Saudi Arabia	1
South Korea	1
Germany	4
Israel	2
Ireland	1
Great Britain	1
Switzerland	1
Canada	1
Total	40

Figure 8 ***Source:*** Thomson Innovation Patent Database, 2013 (analyzed by author)

Such arrangements are found to be both within international firms and in academia. For example, in the USA, out of 16 such collaborations, eight were related to USA multinational firms and eight were related to USA university bodies (Figure 9).

These institutional and human resource collaborations, as a part of the wider international system of innovation, are indicative of the international S&T cooperation in emerging technologies.

CONCLUSION

While mapping the Indian nanotechnology innovation system, the following observations have emerged.

It is clear from the preceding that the public universities are the main source of knowledge generation in the area of nanotechnology, followed by government research centres and laboratories; where its application in terms of patenting is concerned, the public research labs play a more dominant role in India.

USA universities/companies with Indian Inventors
CORNELL CENTER FOR TECHNOLOGY ENTERPRISE AND COMMERCIALIZATION
GENERAL ELECTRIC COMPANY
HALLIBURTON ENERGY SERVICES INC.
LAIRD TECHNOLOGIES INC.
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
APPLIED MATERIALS INC.
THE BOARD OF TRUSTEES OF THE UNIVERSITY OF ILLINOIS
DREXEL UNIVERSITY
PURDUE RESEARCH FOUNDATION
UNIVERSITY OF SOUTH CAROLINA
SAINT-GOBAIN ABRASIVES INC.
NANOGRAM CORPORATION
TRUSTEES OF BOSTON UNIVERSITY
NATIONAL SCIENCE FOUNDATION
CONCEPT MEDICAL INC.
CNANOZ INC.

Figure 9

The private sector has revealed great potential and could play a significant role in future.

India has attracted collaboration mainly from the developed countries and only a few developing countries figure as the top collaborators.

It is also evident from the patent analysis that Indian inventors were part of the research teams of around 10 countries involved in international patents on nanotechnology.

Recently, India has emerged as one of the major destinations of inward and outward FDI, migration of knowledge workers, R&D collaborations, institutional linkages, inventor collaborations, technology intensive export and international institutional engagement.

In the context of the foregoing, it is clear that the interactions between the national and international innovation systems can no longer be ignored.

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