TRANSFORMING SCIENCE TO TECHNOLOGY: RELATIONSHIP BETWEEN SCIENCE, TECHNOLOGY AND PATENTS- A LITERATURE REVIEW

2.1. Literature Review

This review will elaborate importance of science & technology and the factors that drive economic development of an organization. The challenges of converting science to technology and further scaling it up for commercialization are the main features to be highlighted. If the Indian research community can focus on converting science to technology, the progress of knowledge economy will be enhanced along with benefits to the original inventor. This literature review helps to know the importance of science and patented science. Further it discusses how these factors need to be considered by research community to convert science to technology.

Science & Technology are significant drivers for financial growth in the emerging economy. The more essential they turned into, the more the need was perceived to screen their advancement, to analyze the conditions under which they achieve an ideal performance and to figure and execute the policies for improving its execution and defining its needs\(^1\).

The relationship between S&T becomes one of the crucial issues for science policy guidance, innovation and economic studies. It is commonly believed that science and technology are closely connected, interacting and interdependent. In 21\(^{st}\) century or post 2\(^{nd}\) World War, S&T are the driving forces of the nation and drivers of economic development.

Information diffusion between science and technology is the adaptation of information and flow of knowledge, between science and technology. Information flow or interaction between science and technology takes many different forms, each working in a specific way and types of indicator. For example, knowledge and information may be shared by various channels like personal meeting at seminars and workshops, or by change of workplace by researchers, by students joining researcher for joint research projects, or by way of publication such as scientific articles and patents\(^2\).

In literature two ways for studying the information diffusion between S&T have been identified, namely, 1.'indirect linkage' 2.'direct linkage'. The former tries to understand the S&T linkage via

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mobility of scientists or engineers and the latter uses bibliographic information in publication and patent documents.³

Academics and policy makers are investigating the relations between S&T in different disciplines. Number of efforts on theory and model exploration as well as empirical studies have been undertaken to uncover the nature and type of the relation and interaction between S&T.⁴

2.2. Relationship between science and technology

The relationship between S&T becomes one of the crucial issues for science policy guidance, innovation and economic studies. A number of efforts on theory and model exploration as well as empirical studies have been undertaken to uncover the nature and type of the relation and interaction between science and technology⁵.

Toynbee compared the Science & Technology interaction to a "pair of dancers" and he found it hard to decide who actually pushes whom⁶. As Toynbee also has pointed out, it is difficult to distinguish between science and technology. Consequently, later studies pointed out the multifaceted relationship between science and technology and the "linear model" was replaced by the "network model". The "network model" is definitely more adequate to characterize the complex relation between actors in S&T system and led to the insight that it is too simplistic to think of the technology dependence on science⁷.

Science and technology sources in the form of articles and patents respectively, are valuable sources of knowledge. They contain important research results that are valuable to the researchers, scholars, industry experts and policy-making communities. Since the information age and the knowledge economy, the availability of information in digital format has tremendously grown and is continuously increasing. During the past decade the World Wide Web has become a most important general source of information. More and more scientific and technological information, are made available and actually retrieved through the web. The comprehensive coverage of research papers published in many thousands of online peer-

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reviewed scientific and technical journals like Thomson/ISI Science Citation Index or the Web of Science, and the patent databases such as the USPTO, EPO and the Japan Patent Office (JPO) are valuable sources of information used in quantitative studies of S&T systems. Analyzing these data sources systematically could help policymakers, administrators, R & D managers, scientists and scholars getting familiar with progress in different science and technology fields and provide them with an insight for future planning. For a long time, the science and technology (S & T) relationship was depicted through the "linear model" which emphasized the technological progress dependence on scientific discovery. Some retrospective studies were conducted based on this "linear model" for revealing the contribution of basic research to technology development. However, the "linear model" unilaterally stressed the influence of scientific research on technology development and ignored that technology often shaped science in important ways.

During the second half of the 1990s, the Triple Helix model drew attentions on the interaction between companies, academic institutes and government and was widely used in science and innovation policy. Bilateral relations between government and academic institutes, institutes and companies and government and companies in Triple Helix model have expanded into tripartite relationships among the spheres. Where the institutional spheres overlap, collaborate and cooperate with each other. Today, as markets and technologies are rapidly changing and product life cycles become ever shorter, firms continue to develop and introduce new products to market places worldwide that form part of their core competency. Firms have used a variety of methodologies to derive new ideas and direct them to the best development paths for creating the next generation of products and related technologies. These methodologies range from general methods including brainstorming, user analysis, benchmarking, technology forecasting, Delphi, etc. to specific techniques such as quality function deployment (QFD), which is used to link customer needs and product attributes, TRIZ to generate inventive ideas for problem solving analytic hierarchy process (AHP) to analyze multiple new product development (NPD) scenarios and technology road mapping (TRM) to connect product planning and technology planning.

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Providing meaningful information from S&T data bases can help experts get acquainted with recent progress in science and technology and will add to the efficiency of pre-mentioned methods.

Scientific advancement and technological innovation are becoming key drivers of economic progress in knowledge oriented capitalist economies where development, efficiency, and competitiveness are completely based on better technologies, innovative products, advance processes or customized services. The creation of radically new knowledge, improving existent knowledge, or imitation of others, has become central to economic development.

Evaluating science-technology relations and tracing the transfer of knowledge from science to technology or technology to science, are crucial issues for understanding the knowledge society and addressing S&T policy questions. It provides tools for S&T monitoring and determines the orientation of R & D policies.

Measuring science and technology in a quantitative manner, is crucial to understand and interpret the relational structure of both science and technology spheres. Several quantitative, particularly bibliometric indicators have been established and applied to determine the linkage between science and technology\textsuperscript{12}. In most of the studies conducted in this area scientific articles are considered as Reflector of science and patents have been looked upon as Reflectors of technology.

Creating the mechanism for supervising and tracking science and technology developments and knowledge transfer between them has lots of benefits. It helps policy makers and executors to design the strategic plan, priorities on the research areas and identify the knowledge gaps in different areas. It also aids researchers, academia and technocrats to keep updated with science and technology trends. It helps companies to meet the complicated customer demands and lead their competitors, nationally and globally. It also helps them in monitoring and tracing their competitor's behaviour\textsuperscript{13}.

With the high usage of digital data, the volume of e-documents and the quantum of knowledge available through internet frequently beat the R & D teams. Organizations are utilizing an ever expanding number of electronic knowledge documents. Engineers and researchers, in particular, are retrieving and processing large numbers of technical reports and patent documents to


safeguard existing intellectual properties and to avoid infringing upon the rights of others\textsuperscript{14}. For individuals and organizations alike, this overwhelming amount of digital data leads to major difficulties to find and process relevant information and knowledge. As Trappey mentioned in his research, information retrieval should be complemented with other algorithms to move beyond the mere finding of interesting documents. Lack of time and budget for R & D teams do not allow them to spend more on documentation, thus are always overloaded with information\textsuperscript{15}. Although the internet has greatly facilitated the search and retrieval of knowledge and search engines are essential to find relevant information, they often return a mass of irrelevant results within very long result lists. Existing classifications of science are inherently outdated because of the pace at which scientific knowledge advances.

Strategic planning for S&T development and research progress needs to have in depth understanding of S&T progress. The high speed of S&T progress and abundant data accessible on internet makes it tough for researcher to pick useful content without powerful tools. Data mining techniques will help in picking the useful content out of documented resource\textsuperscript{16}. Monitoring science and technology evolutions is the prerequisite of effective future R & D planning. It helps policy makers get acquainted with progress in different knowledge fields. Governments face with uncertainty when they want to divide their budget in different fields. They must decide on the way of spending their R&D resources. This specially is crucial for developing countries. They have to find out their knowledge capabilities and determine making progress in which field could become source of competitive advantage for them in future.

Organizations invest huge amounts of money for developing new products which after reaching to "mass production level couldn't find good market and the investment become useless. This usually happens because R & D managers or product design team in organizations may not consider the behaviour of their competitors and substitute products or technologies. One of the main reasons that cause new products or new technologies do not face with good market is not having enough knowledge about trend and speed of progress in different knowledge fields.

Information in patent literature and scientific papers are excellent sources of gathering knowledge.

Keeping track of these developments can help administrators, policy makers and experts in better planning of resources in anticipation of future of technology. Text mining techniques we try to develop some tools for better monitoring and tracing science and technology evolutions. Study the information diffusion between patents and scientific articles are one way that can help organizations find areas that need more interaction with academic places, they could find in which area patenting is more common and find areas that putting effort on them would be a good business opportunity for future. Developing framework for comparing science and technology behaviour is an efficient tool for strategic planning in different science and technology disciplines.

In order to reach to these purposes, approaches to evaluating science and technology interaction were studied. Analyzing occurrence of inventor names in patents and author name in scientific papers was studied to measure the information diffusion between patents and scientific articles. This will help in

1. Investigating different methods of evaluating science and technology interactions based on information in scientific articles and patents.
2. Developing a framework for evaluating science and technology evolutions by using scientific articles and patents databases.
3. Helping policy makers, administrators and R&D managers, in their future strategic planning by monitoring information diffusion between scientific articles and patents.
4. Finding areas that have strong linkage between science and technology by matching common information between patents and papers.

2.3. Science & Technology as source of competitive advantage

Scientific research and more specifically basic scientific research, is a major dimension of this capacity to absorb and to internalize new knowledge. Spill-overs originating from the scientific literature are an important dimension of knowledge accumulation and growth\(^\text{17}\). At macro-economic level, a nation's innovation capacity is a major driver for (sustained) economic

growth\textsuperscript{18}. Competitiveness is at least partly the result of an actor's capacity to create, trace, absorb and to assimilate new technological and scientific evolutions - the so-called absorptive capacity. In science-based technologies and sectors (i.e. technologies closely related to scientific progress), especially in newly emerging fields, the capacity to create and to absorb state-of-the-art research is of critical importance for developing and maintaining a strong technological position\textsuperscript{19}.

At micro-economic level, ability to extract knowledge from science and technology toward innovation enables firms to respond to ever more sophisticated consumer demands and stay ahead of their competitors, both nationally and globally\textsuperscript{32}. Outputs from research and development and S & T were linked to productivity of organizations, sales of new products, profitability, and similar economic variables\textsuperscript{20}. Knowledge is nowadays generally accepted as a fourth production factor (besides labour, land and capital) accounting for a major portion of the variation in economic growth and development between nations and continents\textsuperscript{32}. The speed of technological advancement, the industrial structure of countries and the speed of scientific progress are all means of measuring countries economic growth.

Technology-based economic growth is increasingly dependent on product differentiation and strategic strengths in novel technological fields. The genesis of some of these emerging fields can be traced to the close interaction between universities/public research institutions and industries\textsuperscript{21}.

One of the reasons Europe has generally been depicted as lagging behind the US in terms of technology development is, because of its inability to successfully translating science and technology into market applications and subsequent revenue generation (See European Innovation Scoreboards (2007) and (2002). The importance of science and technology (S & T) in discovering new knowledge, driving market innovations and delivering public goods has accelerated in recent decades\textsuperscript{22}. In order to have S&T as resource to create of competitive edge, it


is important to have a strong and well-coordinated interaction between government, academic institutes and companies.

2.4. Science and Technology interaction

One might find it difficult to judge whether science pushed technology or technology pulled science. Martin Meyer did a survey on this matter. His result pointed to the increasingly intertwined relationship between scientific and technological activities. He also indicates the kind of closeness between the two spheres. For instance, he illustrated a close personal science-technology linkage by individuals working on one subject-matter in both scientific and industrial organizations. It seems to be a much more reciprocal relationship than the linear model suggests. Verbeek and his colleagues in their study of linking science to technology mention that the use of the linear approach is largely ignored due to the following reasons:

1. The empirical evidence that technological change often resulted from experience and ingenuity rather than from scientific theory or method
2. The instrumental role of technological developments in inducing scientific explanation the importance of technology-based instrumentation for scientific investigation

Over the last three decades, different ways of approaching the science and technology interaction have been emerged. At first, the knowledge transfer from science to technology was considered to be linear and science and technology were viewed autonomously. This approach is highly criticized in literature.

De Solla Price developed a two-stream model based on citation analysis of science and technology journals. This model stresses the autonomy of science and technology as cognitive systems and the reciprocal nature of their interplay. Tracing citations in science and technology journals, De Solla Price found separate cumulative structures with scientific knowledge building on old science and technology on old technology. He also detected a weak and reciprocal interaction between the two. De Solla Price saw in his 1965 study the closest interaction between

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24 Verbeek et al., Linking science to technology: Using bibliographic references in patents to build linkage schemes, Scientometrics 543: 399-420 (2002).
science and technology taking place in the period of education when budding scientists read the archival literature in their fields.²⁵

At present, the linear approach has evolved toward a "network model", which views the relationship between science and technology as more reciprocal and interactive. The "network model" of knowledge production, transfer and utilization is therefore more likely to characterize in a more adequate manner the complexity of the interactions between the producers and the users of knowledge.²⁶ Meyer acknowledges that the old 'linear model' is "simplistic and highly inaccurate," and he also says that it "ignores the much more intimate relationship between science and technology."²⁷

Scientific and technological activities are most likely to run in parallel especially in fields that are characterized by a high rate of innovation, such as pharmaceuticals and telecommunication. Obviously, the level of science-technology interaction varies from field to field. Different fields have a different nature of interaction.³⁹

As triple helix model also mentioned, information flows within the network are now more easily accessible to governments and firms, increasing their influence on specialization, co-operation and competition in techno-scientific development. A such, it is more appropriate to conceive the relationship between science and technology as a reciprocal one characterized by an intricate inter-woven nature and consider them as separate but closely interacting partners whereby scientific exploration and technological exploitation mutually influence each other.²⁸ Some industries rely on science to a larger extent than others. There are also considerable differences between technological sectors in their propensity to patent.²⁹

Diffusion lag also is an important parameter in science and technology interaction. According to the research done by Adams, Clemmons and Stephan, the modal or most frequent lag in science citation is 3.0 years between universities and from universities to firms. The modal lag in science citations between firms is 3.3 years, about three month longer than the lag involving universities. This result suggests that publication and diffusion are delayed only slightly in industry. This

²⁶ Verbeek et al., Linking science to technology: Using bibliographic references in patents to build linkage schemes. Scientometrics 543: 399-420 (2002).
result was 4.8 years for patents. Thus science diffusion appears to take place about fifty per cent more rapidly than technology diffusion\textsuperscript{30}. At the technology level empirical evidence shows that in several fields of technical activity, an increased level of scientification has occurred. ARI and his colleagues (1997) led the way in pioneering this research effort. Especially, as they have stated, in young and rapidly developing fields one may find a higher degree of science involvement\textsuperscript{31}.

\textbf{2.5. Methods of evaluating science and technology interactions}

There are many ways in which one can study the relationship between science and technology\textsuperscript{32}. Since the advent of electronic means of communication like the internet, both scientific and technological information have become more accessible. Informatics means such as analysis of co-publications of industrial firms, university patenting, or patent citations are several ways of measuring this direct interaction\textsuperscript{33}.

Different ways of measuring science-technology interaction in direct approach have been listed below\textsuperscript{34}. Verbeek, Debackere, Luwel and Andries distinguish two approaches for studying the relationship between science and technology: the "indirect" linkage approach and the "direct" linkage approach. The "indirect" linkage approach tries to understand the S&T linkage via mobility of scientists and engineer the educational process etc. The "direct" linkage approach refers to the possibility of studying the S&T interaction through the bibliographic references present in the scientific publication and patent documents\textsuperscript{35}.

\textsuperscript{35} Verbeek et al., \textit{Linking science to technology: Using bibliographic references in patents to build linkage schemes}, Scientometrics 543: 399-420 (2002).
2.6. Different ways of measuring science-technology interaction

These are presented as below:

1. Citation based methods

It exploits the references field of patent or publications. Analyzing non patent references in patents is the most common way in this method\textsuperscript{36}

2. Co-activity methods

It analyses academic patents, cooperation of academic scientists with industry, and co-activity studies of academic institutions and industrial organizations\textsuperscript{37}

3. Category sharing methods

It tries to find coordination between classification schemes of publications and patents although there are basically not commensurable CA of Chemical Abstract Service.

4. Topic sharing methods

It is the lexical way that uses IR - Information Retrieval formulae/ weighting or text mining technique.

5. Hybrid approaches

It combines several informetric ways and measures science-technology interaction with different perspectives\textsuperscript{38}.

In citation based method, the ‘references’ field of patents or publications is analyzed. The analysis of references to non-patent literature in patent documents is now considered as the classic way of investigating science and technology interaction. A good indicator of interaction might combine the two directions of citations despite the fact that scientific publication rarely tended to cite patents\textsuperscript{49}. Co-activity methods may take many forms. Scientists may take patents through their university, through industrial partners or personally. They may themselves have only academic affiliations or be part-time academe/industry. Some of these configurations have been investigated by Meyer and his colleagues\textsuperscript{39}. Category sharing methods try to find common classification themes in different methods of science and technology classification. Generally


\textsuperscript{38} Leydesdorff, L, M. Fritsch, \textit{Measuring the knowledge base of regional innovation systems in Germany in terms of a Triple Helix dynamics}, Research Policy, 35(10), 1538-1553 (2006)

speaking, classification schemes of science and technology are basically not commensurable. Whereas patent classifications belong to the strongly codified framework of patent offices, with, in fact, two basic official nomenclatures, USPTO and International Patent Classification (IPC) and variants, there is no commonly accepted scientific nomenclature, so that in bibliometric practice databases’ classifications are mostly used: ISI's journal lists and INIST Pal classification scheme for multidisciplinary databases. Topic sharing method is the lexical way that uses information retrieval and text mining techniques for tracing science and technology evolutions. Topic sharing of publications and patents can be assessed by various proximity measures between individual documents and/or sets of documents of the two kinds. At first document contents have to be extracted and represented in ways amenable to quantitative processing. Various combinations of linguistic and statistical methods are used originating in Computational Linguistics, Information Retrieval, and Natural Language Processing, with possible labour division between database, dynamic interfaces, and further analysis by bibliometricians/users. Hybrid approaches combine several info metric ways and measures science-technology interaction with different perspectives. Best way of measuring Science & Technology interaction is through exploiting and combining several ways of measurement so that different aspects of this interaction can be evaluated.

2.7. Scientific publications as indicator of science

The role of science for technological advancement has received a special focus in research and the policy communities. Scientific literatures from bibliographic databases are considered as a centralised source of information. They are the most authoritative records of research. Databases such as the Science Citation Index (SCI) contain detailed record of these papers and citations to them from other papers allowing detailed analysis.

The prime goal of the scientific publication is to share the scientific outcomes with the community. Hence, publication in scientific journals plays a leading role in the dissemination of

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the findings of science. They can be used to trace knowledge now and can describe the linkage structure and intensity of those flows.43

2.8. Publications and patents as means to analyze S&T interaction

Scientific publications and patent database are leading sources for R & D policymakers since data are collected in one place and repeatedly updated, the longitudinal analysis could be done easily and the data has standard structure and the definitions and categories change slowly44.

In most of the S & T interaction studies, papers are viewed as representations of science, while patents are considered as representation of technology45. The information in patent literature can be used for planning purposes. Patent documents contain important research results that are valuable to the industry, business, law, and policy-making communities. If carefully analyzed, they could be a strategic information source that show technological details and relations, reveal business trends and inspire novel industrial solutions.

Traditionally, companies prefer patenting over publication, and university researchers prefers publication than patenting. As Meyer states that research done in big corporate are able to command about 80% of all patents, and most of the remaining 20% are granted to individuals or owner of small companies46. The researcher at the academia prefers publications against the researchers working in business firms. Thus, the linking of patent with business firms and publication with academic institutes is natural47. Many scientists and economists believe that public science is a motivator for technology advancement and economic development. They also believe that the transfer of outcome of publicly funded research to companies is an important step of the technology transfer48.

2.9. The metrics of bibliometrics

Bibliometrics is the field of science that deals with advancement and application of quantitative measure and indicators for S&T, based on bibliographic information. This bibliographic information is the representation of codified knowledge as can be found in a diversity of scientific output types such as serial literature, books, and book chapters, conference proceedings, patents etc.\(^{49}\) It measures the outputs that are proximal to the scientific activity that is, the client outcomes that science generates.\(^{50}\) Industrial companies use bibliometric measures in two complementary forms. The first is the evolution of the performance of their scientific personnel within the R & D unit and activity. The second is the evaluation of the R&D functions within the firm. In general, companies use bibliometrics as an integral part of their system that evaluates scientific and technical employees. Widely-published corporate researchers indicate an outstanding R&D group and generate much desired reputation and prestige for the company. Companies hold the belief that the reputation of their scientific cadre will permeate onto their customers, other stakeholders, and the general public. In summary, industrial companies utilize bibliometrics because they believe that by supporting a climate of research and publishing the firm fosters the intellectual enrichment of its personnel. This, in turn, will ultimately translate into contribution to the bottom-line through innovations, added prestige, and sustained competitiveness.\(^{51}\) Publications offer usable elements for 'measuring' important aspects of science. Although not perfect, we adopt a publication as a 'building block' of science and as a source of data. This approach clearly defines the basic assumptions of bibliometrics. When the results and findings from the R&D activity are published, over a time a database of knowledge is thus created, and this becomes the state-of-the-art (SOA) of the discipline. Within this database, scientists also compute the citation analysis which is a process by which citations of articles in the literature are counted and analyzed to show and to study emerging patterns.

**Strengths and weakness of the use of bibliometrics**

Although bibliometrics is a relatively simple; inexpensive and valid metric of the intellectual outcomes from science, but it is not free of problems. The use of serial literature is not evenly

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\(^{50}\) GEISLER, E., THE METRICS OF SCIENCE AND TECHNOLOGY- Westport, Quorum Books (2000).

distributed over fields of science (for instance, the dominant use of conference literature within some fields of the technical sciences), bibliometric studies is based on the pretext that the most significant outcomes of scientific research finally end up in the serial literature. This, however, means that, in general, bibliometrics is less applicable in those fields of science in which the internationally oriented scientific journal is not the main medium for communicating research findings to the (international) community in those fields.

Bibliometrics has a variety of strengths. Geisler divided these strengths in to three categories: structure, measurement, and representation\(^5\). The structure category includes those strengths that allow for multiple levels of analysis, and a relatively adequate cost for analyses. In the measurement category, the strengths suggest that the data are available and the analysis is straightforward, making it a relatively simple procedure to plan and to undertake. Finally, bibliometrics is considered by the S&T community to be a valid representation of the phenomenon of outcomes from inventive activity. Bibliometrics are best employed in the evaluation of the scientific component of knowledge creation. But, when applied downstream the innovation process, this metric describes only one, perhaps very small attribute of the phenomenon of R & D and technological development, utilization, and commercialization by the firm. Hence, bibliometrics must be regarded as a limited measure of the upstream activity and outputs, whereas other metrics should be used to assess downstream activities of the innovation process.

### 2.10. Bibliometrics as S & T indicator (Table 2.1)\(^6\)

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<th>Strengths and benefits</th>
<th>Weaknesses and Problems</th>
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<tr>
<td><strong>A. Structure (strength / benefit)</strong></td>
<td><strong>A. Coverage (weakness / problem)</strong></td>
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<tr>
<td>• Bibliometrics can be applied to various levels of generators of intellectual outputs, such as individuals, groups instructions and countries.</td>
<td>• Published articles are only one measure of outputs from scientific activity; hence the metric does not cover reports, other written communications such as electronic mail, letters, and personal communiqués.</td>
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<td>• The cost of collecting the data and</td>
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conducting meaningful analysis is relatively adequate.

- The measures are already built into the metric, thus there is no need to establish them and to test them for validity.

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<th>B. Measurement</th>
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<tr>
<td>• Bibliometrics allows for quantitative assessment of S&amp;T outputs by counts of papers and citations, and for qualitative assessment by analysis of core journals and their relative impacts.</td>
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<td>• Bibliometrics and its analysis is a relatively straightforward approach, relying on a few assumptions.</td>
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<th>B. Measurement</th>
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<tr>
<td>• Articles published in peer-reviewed journals and their citations analyses disregard the outputs and intellectual contributions in articles published in technical outlets, as well as work-in-progress.</td>
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<th>C. Representation</th>
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<td>• Bibliometrics can be applied to the entire spectrum of S&amp;T where outcomes take the form of reports, papers, citations</td>
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<th>C. Generalizability</th>
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<td>• Counts of publications and citations lack a standard for their validation as a measure of quality. When compared with inputs</td>
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- Bibliometrics, through citation analysis, help to determine the role that individuals and institutions have in the evolution of a scientific discipline.
- Bibliometrics defines how the science and technology have developed in various scientific disciplines.
- By convention, bibliometrics has been accepted by the S&T community as valid representation of the outputs from intellectual and inventive activities.

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<th>(investments in R&amp;D), the resulting analysis relies on co variation of two distinct phenomena and disregards the complexities of the R&amp;D process.</th>
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<td>- The only standard for validation of bibliometrics is convention of a small and elite group of influential scientists.</td>
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<td>- As in the &quot;Hindsight&quot; project, the problem is: &quot;How far in time should citations go?&quot; Should articles in quantum mechanics cite Einstein's work and that of the Greek philosophers and mathematicians?</td>
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<tr>
<td>- Citations are thus highly selective and refer to a relatively short timeframe, preferably within a few years of the focal paper in which they are cited</td>
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### D. Biases

- Because of the almost incestuous nature of the small group of prolific publishers, there is an inordinate amount of self-citations and citations of "friends" and other members of this elite group. Thus, authors who publish in areas those are near the boundaries of their discipline or in cross disciplinary topics are much less likely to be published in top journals or to be cited in them.
- Criteria for the selection of articles for publication in juried journals are built into the process and will bias the resultant counts of papers and citations in favour of
those authors preferred by the reviewers.

- Selection and analyses of key journals and the interpretation of the counts of papers and citations are based on assumptions of validity of these metrics as measure of quality and internal dynamics of the discipline. Such assumptions are the product of opinions and judgment, hence biased.

- The selection and analysis process of key journals and papers to be included in this process is biased in that analysts who are generally outside the discipline or the area impose their own views and criteria in making determination and drawing conclusions that transcend the data. This list is not exhaustive nor in any specific order.

2.11. Patents as indicator of technology

Patent documents are important indicators of technology growth. The challenge to make the Indian researchers understand the importance of patenting a technology is an important factor. The following description helps to understand the importance of patents as indicator of technology.

As a measure of S & T, patents are considered by many economists to be indicators not only of inventive activity but also of technological progress and change at the industrial and national levels. Patents are considered to be "tangible evidence of technological innovation, "therefore they are considered a reliable measure of technological capability and achievement"54.

Patent definition
A patent is an exclusive right granted for an invention which requires technical information to be disclosed. The assignee can bestow his right to other party through licensing on mutual terms. On the end of tenure of patent protection, the invention becomes public property.

The Structure of a Patent Document
Publicly available patent documents contain a wealth of information such as:

- Name and addresses of inventor(s):
- Invention characteristics:
- Name and addresses of the patent assignee(s):
- Date of filing:
- Technical class of the patent:
- References to other patents and scientific literature.

This information can be used in tracking advance in technology. They have been used in wide variety of studies to explore the nature, sources, and economic effects of technology. Ganguli and Blackman (1995) review the structure of a patent document, and divide it in three parts:

1. The title page with bibliographic information;
2. The text, which includes a description of the invention, preferred examples in details as well as drawings, diagrams, and flow charts;
3. The claims.

Main sources of patents & their differences
Statistics shows that the USPTO, the EP and the Japan Patent Office (JPO) issue nearly 90 percent of the world's patents. There are, of course, many fundamental differences between

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main sources of patents. For example some of the main differences between the U.S. patent system and the EPO system, include\textsuperscript{59}:

- The European system is a "first to file" system, where priority rights are based on the first person to file a patent, whereas the U.S. is a "first to invent" system, where priority right to an invention are given to the person who can prove that he first invented it. This has changes in US after March 2013.
- In the European system patent applications are published 18 months after application, usually with search reports. The U.S. system also publishes patents after 18 months from date of filing. This change was after 2001.
- The US patent office requires description of the invention and list of references during filing of application. The European patent office does not mandate reference list. The US patent office thus has a legal requirement to site all references.
- Finally, it should be mentioned that in the U.S. system there are many other science references contained in the body of a patent which are very similar in general nature to the references on the front page.

2.11a. Patent analysis

The detailed information contained in the patent documents is valuable source for analysis. One can study the geographic distribution of particular inventions based on the country information, one can investigate technology trend in different patent classes, and one can actually read the detailed text of a series of patents in a particular field as raw material for an economic technological history of it\textsuperscript{60}.

Patent analysis can be done based on the following information in patent document:

- Statistical information such as the names of inventors and their addresses and the name of the organization to which the patent right may have been assigned
- patent classes to which it has been assigned by the examiners
- Information about cited and citing references
- Detailed description of patents through text mining techniques


Patent analysis consists of following seven steps which can be compressed or expanded as appropriate:\(^{61}\):

1. **Issue specification and data source(s) selection** which the research topic and its objective will be clarified. Also the suitable data source for analysis will be selected in this step.

2. **Patent search and retrieval;** Patent search could be done by choosing appropriate keywords, patent number, the name of inventor or assignee based on the research topic.

3. **Data cleaning and pre-processing:** In this step unsuitable data will be omitted from collected data base and desired information will be parsed out from data set. This information could be the name of countries, assignees, inventors, citing and cited references or patent description. Some pre-processing action also will be done in this step.

4. **Data analysis:** Extracting relationships and pattern between processed data could be done in this step. According to research objectives analysis could be done in various ways. For example one could do trend analysis in different technology field by monitoring the number of patents issued in subcategories of that technology field. Or we could trace the organization collaborations based on the common assignee name.

5. **Information Representation:** Extracted knowledge will be visualized in this step by using different visualization and mapping tools.

6. **Interpretation:** Results will be evaluated according to users need in this step.

7. **Utilization:** which the result will be presented for decision maker and after approving will be spread for execution.

2.11b. The utilization of patent analysis

Information obtained through patent analysis can help senior management in assessing a firm's technological competence. In particular, one can distinguish three major applications of patent citation analysis:

1. S&T changes over a period in different fields can be studied which helps in understanding the trend of technology development.

2. Measuring the intensity of science and technology interaction
3. Tracking potential knowledge flows between scientific and technological fields\textsuperscript{62}. The role of patent analysis in strategic planning can be summarized in following items\textsuperscript{63}:

- R&D program management
- Intellectual asset management
- Assessing firm's technology portfolio against competitors assessing the potential of technologies, new technologies creating business opportunities.
- Recognizing strategic changes in the firm's competitive environment
- Evaluate important market partners, especially customers and supplier, to determine if the firm's R&D strategy is in alignment with the R&D strategy of its major customers and if R&D alliances exist with the most competent suppliers
- Assessing the patent situation in new business areas which may be explored
- Improve human resource management regarding leading inventors in specific technological fields.

\textbf{2.11c. Strengths and weakness of patent analysis}

Technology growth can be accessed through patents. It should be considered that although patents have extensive uses and contain valuable information, patent counts and analyses provide only a limited measure of the R&D activity and are not sufficient to be used as a sole metric of R&D. But when used in combination with other metrics, patents offer a manageable piece of data on the level of R&D effort by individual and firms. One should not confuse the relative ease in obtaining such data and their manipulation with the amount of knowledge that such data provide on the R&D phenomenon. Such knowledge is limited, bounded by the weaknesses and problems. Technological growth of a nation is accessed against its productivity which can be measured through the number of patents per capita\textsuperscript{64}. The utilization of data on patents to measure technical and scientific output raises a number of problems\textsuperscript{65}.

- The patent rules varies in every nation and so do the requirements for patenting an invention

• The company, its size, the background of the inventor decide the inclination towards patenting
• It is very difficult to judge the ratio of inventions against the acquired patents making it very tough to judge the research process.
• The "quality" and "value" of patents varies greatly;
• There is no sufficient data available to find out the utilization of patents issued.
• A sizeable amount of patents are filed as a part of strategy, i.e. to control the competition

In particular, patents as a metric are of limited value because of different patenting behaviours by companies, and the fact that they are expected to be a legal instrument offering some measure of protection of intellectual property. They were not specifically designed as a metric of either the R&D activity or its outcomes\(^6\).

**Patents as S&T Indicator (Table 2.2)**

<table>
<thead>
<tr>
<th>Strengths and Benefits</th>
<th>Weaknesses and Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B. Methodology</strong></td>
<td></td>
</tr>
<tr>
<td>• Patent data are quantitative measures.</td>
<td>• There are marked differences among firms and industries in the propensity to patent inventions.</td>
</tr>
<tr>
<td>• Patent databases have been in existence for many years.</td>
<td>• Industrial firm only spend less than 1/3 of their R&amp;D effort to develop new products that would result in patent.</td>
</tr>
<tr>
<td>• Patent data are relatively easy to manipulate.</td>
<td>• Firm-specific information in patent data impacts decisions to invest in S&amp;T.</td>
</tr>
<tr>
<td>• Patent data can be related to other economic/financial measures.</td>
<td>• Past performance of patenting activity impacts the propensity to patent.</td>
</tr>
<tr>
<td>• Patent citations allow for co-citation analyses.</td>
<td></td>
</tr>
<tr>
<td><strong>C. Firm-Industry Strategy</strong></td>
<td></td>
</tr>
<tr>
<td>•</td>
<td></td>
</tr>
<tr>
<td><strong>D. Structure</strong></td>
<td></td>
</tr>
<tr>
<td>• Patent data have a similar structure as a legal document.</td>
<td>• Distortions in market due to monopolistic behaviour.</td>
</tr>
<tr>
<td>• Contain revealing information.</td>
<td>• Market factor may impact patenting</td>
</tr>
<tr>
<td><strong>D. Market Considerations</strong></td>
<td></td>
</tr>
<tr>
<td>•</td>
<td></td>
</tr>
</tbody>
</table>

- Indicate levels of S&T effort.
- A similar item of information facilitates cross-industries and even cross-national comparison.

### E. Impact and Contributions
- Considered as a link between S&T and firm performance, patents offer an elegant way of establishing such a link.
- Patents are viewed as indication of technological achievements.
- Patents are viewed as measures of the knowledge-base.
- Patents are viewed as measures of the quality of S & T.

### E. Structure and Methodology
- Patents represent only a small portion of the actual R&D and S&T effort.
- Patents reveal only elected information about S&T.
- Patentable inventions have become increasingly harder to discover.
- The link S&T-Patent-Performance is based on co variation methodology and lacks a description of the process and factors that impact this presumed link.
- There is a lack of a theory to explain how patents contribute to performance and to strategic advantages (except for the link to possibly monopolistic manifestation of the power from patent protection).

### 2.12. Transforming science to technology: overview of tech transfer in CSIR:
Transforming science to technology can be defined as an activity where the new discoveries and novel ideas are made open to public for use. This transfer of knowledge can occur either through presentations or publications done at conferences or through university-industry technology transfer agreement. In MIT, technology transfer however, refers to the formal licensing of MIT owned intellectual property to third parties such as start-up companies or corporations. As per the data published by MIT, out of the total 2616 issued US patents, more than 50% patents have been licensed to third parties

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67 MIT technology Licensing Office - http://tlo.mit.edu/
Most of the leading universities around the world, are realizing the need to increase commercial activities within the institutes. There is a need to develop models that will help drive positive outcomes of the research developed in the institutions. These outcomes could be in the form of start-ups, licensing of technology or royalty sharing. The other aspect that needs to be considered, is the how the performance of technology transfer can be evaluated. The performance management models help to understand how technology transfer has taken place in the institutes over a period of time, and also provide a complete understanding of the process.

These management tools for performance will help calculate vital individual elements such as:

1. what is done - effectiveness,
2. how it is done - efficiency and importantly
3. overall Return on Investment (ROI)

Every institute have to set up performance management models that line up with their policy, and for transfer of science to technology they must take account of the following points:

1. Increase disclosure of those inventions that are high quality inventions which can be future license products. This can be done by motivating inventors to disclose innovative ideas
2. The technology transfer can be successful only if there is more conversion of inventions to patents. Further these patents should be either licensed or motivate start-ups. These licenses or start-ups should be scaled up to commercialized products which will ultimately lead to profits;
3. The above process will help in self-funding of research by growing license income against the research expense (ROI) incurred.

Based on the 3 vital elements, what is done - effectiveness, how it is done - efficiency and importantly, overall Return on Investment (ROI), a compared analysis of the top performing universities is shown below in table 2.3 (the score in on the scale of 1-10)68:

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## Top Performing Universities with Performance Scores (Table 2.3)

<table>
<thead>
<tr>
<th>Institution</th>
<th>Overall Effectiveness</th>
<th>Overall Efficiency</th>
<th>Overall Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>California Institute of Technology</td>
<td>6.84</td>
<td>9.44</td>
<td>8.23</td>
</tr>
<tr>
<td>New York University</td>
<td>5.24</td>
<td>5.05</td>
<td>5.14</td>
</tr>
<tr>
<td>University of Georgia</td>
<td>4.49</td>
<td>5.42</td>
<td>4.98</td>
</tr>
<tr>
<td>Stanford University</td>
<td>4.47</td>
<td>4.97</td>
<td>4.74</td>
</tr>
<tr>
<td>Northwestern University</td>
<td>4.31</td>
<td>5.31</td>
<td>4.84</td>
</tr>
<tr>
<td>University of Florida</td>
<td>4.02</td>
<td>5.19</td>
<td>4.64</td>
</tr>
<tr>
<td>Georgia Institute of Technology</td>
<td>4.11</td>
<td>5.80</td>
<td>5.01</td>
</tr>
<tr>
<td>Columbia University</td>
<td>4.63</td>
<td>3.72</td>
<td>4.14</td>
</tr>
<tr>
<td>University of Utah</td>
<td>3.44</td>
<td>4.73</td>
<td>4.13</td>
</tr>
<tr>
<td>Massachusetts Institute of Technology (MIT)</td>
<td>4.41</td>
<td>3.86</td>
<td>4.12</td>
</tr>
</tbody>
</table>

**Transforming science to technology - Indian study of CSIR laboratory**

Economy in the 21st century is based on knowledge and transforming this knowledge to commercial benefit. Companies today, face cost cutting issues and thus investing heavy on internal R&D is not affordable. Thus the trend of taking scientific support from external sources is an increasing trend in industries. This scientific support mainly comes from public funded organizations, where they have research and need to commercialize their inventions. Thus a perfect relationship between industry and research organizations is being developed⁶⁹. This has led to the interest of public funded research institutions to protect their inventions through patents and commercialize their new innovations within India. This is indirectly helping the nation to contribute to national economic growth and self-sustenance of research organizations. Post TRIPs implementation, Indian patent filing has increased noticeably. Public funded organizations also contribute majorly to these filings. Many research organizations in India like,

CSIR, DRDO, ICAR and ISRO are taking interest in patent filings. One of the major players in public funded research is CSIR. Council of Scientific and Industrial Research (CSIR) is India’s premium national research and development organization. It is in charge for managing 37 laboratories across the country. Research at the different CSIR labs range from processes and technologies in diverse areas such as materials and petroleum processing, biotechnology, electronics, environmentally sound technologies, aerospace, food technology, chemicals and pharmaceuticals. CSIR is has filed highest number of patents in India constantly for many years. CSIR follows a 2-tier system for technology transfer:

1. Central Project Planning and Business Development Directorate – The department is responsible for developing policies, processes and guidelines for exploitation of knowledgebase and technology transfer
2. Research Planning and Business Development Divisions at laboratories – They are responsible for management of IP, technology transfer and business development and licensing.

CSIR has a well defined IPR policy which gives special importance for stimulation of innovation through its intellectual capital. CSIR has shown a strong scientific excellence which can be understood by its publishing scientific papers in SCI journals, management of human resource of scientific background and IP generated by them. Along with R&D budget provided by the Government, CSIR is also able to generate extra finances through licensing. Scientific contribution by CSIR labs constitutes 11 per cent. Following table 2.4 shows the technology licensed numbers of each lab of CSIR.

### Number of technology licensed by each lab of CSIR (Table 2.4)

<table>
<thead>
<tr>
<th>No. Of technologies licensed</th>
<th>CSIR laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Engineering Sciences (41 licenses)</td>
</tr>
<tr>
<td>1</td>
<td>Central Glass and Ceramic Research Institute, Kolkata (CGCRI)</td>
</tr>
<tr>
<td>2</td>
<td>Central Road Research Institute, New Delhi (CRRI)</td>
</tr>
</tbody>
</table>

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<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
<td>National Aerospace Laboratories, Bangalore (NAL)</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>Central Mechanical Engineering Research Institute, Durgapur (CMERI)</td>
</tr>
<tr>
<td>5</td>
<td>13</td>
<td>National Metallurgical Laboratory, Jamshedpur (NML)</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>National Environmental Engineering Research Institute (NEERI)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Chemical Sciences (198 licenses)</strong></td>
</tr>
<tr>
<td>7</td>
<td>32</td>
<td>Central Mechanical Engineering Research Institute, Durgapur (CSMCRI)</td>
</tr>
<tr>
<td>8</td>
<td>21</td>
<td>Central Institute of Mining and Fuel Research, Dhanbad (CIMFR)</td>
</tr>
<tr>
<td>9</td>
<td>24</td>
<td>National Institute for Interdisciplinary Science and Technology (NIIST)</td>
</tr>
<tr>
<td>10</td>
<td>16</td>
<td>Indian Institute of Chemical Technology, Hyderabad (IICT)</td>
</tr>
<tr>
<td>11</td>
<td>44</td>
<td>Central Leather Research Institute, Chennai (CLRI)</td>
</tr>
<tr>
<td>12</td>
<td>11</td>
<td>Central Electro Chemical Research Institute, Karaikudi (CECRI)</td>
</tr>
<tr>
<td>13</td>
<td>33</td>
<td>National Chemical Laboratory, Pune (NCL)</td>
</tr>
<tr>
<td>14</td>
<td>5</td>
<td>North East Institute of Science and Technology, Jorhat (NEIST)</td>
</tr>
<tr>
<td>15</td>
<td>12</td>
<td>Indian Institute of Petroleum, Dehradun (IIP)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Biological Sciences (164 licenses)</strong></td>
</tr>
<tr>
<td>16</td>
<td>15</td>
<td>Central Drug Research Institute, Lucknow (CDRI)</td>
</tr>
<tr>
<td>17</td>
<td>72</td>
<td>Central Food Technological Research Institute, Mysore (CFTRI)</td>
</tr>
<tr>
<td>18</td>
<td>29</td>
<td>Central Institute of Medicinal &amp; Aromatic Plants, Lucknow (CIMAP)</td>
</tr>
<tr>
<td>19</td>
<td>8</td>
<td>Institute of Genomics and Integrative Biology, New Delhi (IGIB)</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
<td>Centre for Cellular &amp; Molecular Biology, Hyderabad (CCMB)</td>
</tr>
<tr>
<td>21</td>
<td>9</td>
<td>Institute of Himalayan Bioresource Technology, Palampur (IHBT)</td>
</tr>
<tr>
<td>22</td>
<td>20</td>
<td>National Botanical Research Institute, Lucknow (NBRI)</td>
</tr>
<tr>
<td>23</td>
<td>4</td>
<td>Indian Institute of Integrative Medicine, Jammu (IIIM)</td>
</tr>
<tr>
<td>24</td>
<td>6</td>
<td>Indian Institute of Chemical Biology, Kolkata (IICB)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Physical Sciences (23 licenses)</strong></td>
</tr>
<tr>
<td>25</td>
<td>3</td>
<td>National Institute of Oceanography, Goa (NIO)</td>
</tr>
<tr>
<td>26</td>
<td>1</td>
<td>National Geophysical Research Institute, Hyderabad (NGRI)</td>
</tr>
<tr>
<td>27</td>
<td>4</td>
<td>Central Scientific Instruments Organization, Chandigarh (CSIO)</td>
</tr>
<tr>
<td>28</td>
<td>15</td>
<td>National Physical Laboratory (NPL)</td>
</tr>
</tbody>
</table>
The patent filing trends of CSIR show variations from 2006-2010. Foreign filings were reduced during this period. This may be because patent protection is taken up for only those inventions with commercial value or because of the high expenditure incurred for foreign filings. The patent-filing activity and transforming the science patented to technology, it is important to disclose the invention, followed by innovation and assist in creating a niche market for these innovations is the aim of CSIR IP policy\textsuperscript{72, 73}.

Transfer of technology can be effective if the time taken from the initial discovery of product to commercialization of product is reduced. If the speed of innovation to market is accelerated, organizations can fully control research assets, pay back the costs incurred on research projects and help gain profit. For CSIR, this average time from filing patents to licensing of technologies is 3.95 years. However, there are exceptions for some group of technologies licensed by CSIR to the industry. Surprisingly, there are few cases of CSIR where technology licenses were signed before and patents were filed after the agreement\textsuperscript{74}. Thus patents being important for protection of technology in India and also preferred by licensees, may still not necessarily be essential for technology transfer. To find a way to reduce this science to market, legislation - ‘The protection and utilization of Publicly Funded Intellectual Property Bill 2008’ has been designed. Detailed study of this bill is presented further in chapter 5.

### Value generated by CSIR labs through IP commercialization\textsuperscript{75} (Table 2.5)

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Laboratory</th>
<th>No. Of Patents filed</th>
<th>Licensed Technologies</th>
<th>Value generated (Rs.* in billions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Central Scientific Instruments Organization, Chandigarh</td>
<td>93</td>
<td>4</td>
<td>7.8135</td>
</tr>
<tr>
<td>2</td>
<td>National Institute of Oceanography, Goa</td>
<td>134</td>
<td>3</td>
<td>38.2891</td>
</tr>
<tr>
<td>3</td>
<td>Indian Institute of Petroleum, Dehradun</td>
<td>123</td>
<td>12</td>
<td>12.0548</td>
</tr>
<tr>
<td>4</td>
<td>National Chemical Laboratory, Pune</td>
<td>663</td>
<td>33</td>
<td>23.5373</td>
</tr>
<tr>
<td>5</td>
<td>Central Food Technological</td>
<td>570</td>
<td>72</td>
<td>8.8945</td>
</tr>
</tbody>
</table>

\textsuperscript{72} CSIR, Annual Report, 2011-12, Council of Scientific & Industrial Research, New Delhi, 2012
<table>
<thead>
<tr>
<th>No</th>
<th>Institution</th>
<th>Code</th>
<th>City</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Research Institute, Mysore</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Central Institute of Medicinal &amp; Aromatic Plants, Lucknow</td>
<td>164</td>
<td>29</td>
<td>3.4421</td>
</tr>
<tr>
<td>8</td>
<td>Centre for Cellular &amp; Molecular Biology, Hyderabad</td>
<td>59</td>
<td>1</td>
<td>18.9192</td>
</tr>
<tr>
<td>9</td>
<td>Central Drug Research Institute, Lucknow</td>
<td>221</td>
<td>15</td>
<td>14.1892</td>
</tr>
<tr>
<td>10</td>
<td>Indian Institute of Chemical Technology, Hyderabad</td>
<td>540</td>
<td>16</td>
<td>28.4269</td>
</tr>
<tr>
<td>11</td>
<td>Indian Institute of Integrative Medicine, Jammu</td>
<td>164</td>
<td>4</td>
<td>5.3664</td>
</tr>
<tr>
<td>12</td>
<td>Institute of Genomics and Integrative Biology, New Delhi</td>
<td>205</td>
<td>8</td>
<td>10.0961</td>
</tr>
<tr>
<td>13</td>
<td>Central Leather Research Institute, Chennai</td>
<td>161</td>
<td>44</td>
<td>9.9145</td>
</tr>
<tr>
<td>14</td>
<td>Central Electro Chemical Research Institute, Karaikudi</td>
<td>77</td>
<td>11</td>
<td>4.901</td>
</tr>
<tr>
<td>15</td>
<td>National Institute for Interdisciplinary Science and Technology</td>
<td>175</td>
<td>24</td>
<td>9.2728</td>
</tr>
<tr>
<td>16</td>
<td>Central Mechanical Engineering Research Institute, Durgapur</td>
<td>459</td>
<td>32</td>
<td>7.4247</td>
</tr>
<tr>
<td>17</td>
<td>North East Institute of Science and Technology, Jorhat</td>
<td>77</td>
<td>5</td>
<td>6.4172</td>
</tr>
<tr>
<td>18</td>
<td>National Geophysical Research Institute, Hyderabad</td>
<td>58</td>
<td>1</td>
<td>27.9277</td>
</tr>
<tr>
<td>19</td>
<td>National Aerospace Laboratories, Bangalore</td>
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<td>1</td>
<td>13.842</td>
</tr>
<tr>
<td>20</td>
<td>Central Road Research Institute, New Delhi</td>
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<td>9</td>
<td>4.4378</td>
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<tr>
<td>21</td>
<td>Institute of Himalayan Bioresource Technology, Palampur</td>
<td>91</td>
<td>11</td>
<td>8.3468</td>
</tr>
<tr>
<td>22</td>
<td>Central Glass and Ceramic Research Institute, Kolkata</td>
<td>91</td>
<td>11</td>
<td>8.3468</td>
</tr>
<tr>
<td>23</td>
<td>National Botanical Research Institute, Lucknow</td>
<td>182</td>
<td>20</td>
<td>5.0836</td>
</tr>
<tr>
<td>24</td>
<td>National Aerospace Laboratories, Bangalore</td>
<td>38</td>
<td>4</td>
<td>50.1492</td>
</tr>
<tr>
<td>25</td>
<td>Central Glass and Ceramic Research Institute, Kolkata</td>
<td>98</td>
<td>15</td>
<td>11.4268</td>
</tr>
<tr>
<td>26</td>
<td>National Metallurgical</td>
<td>104</td>
<td>3</td>
<td>12.1189</td>
</tr>
</tbody>
</table>
From the table it can be observed that Central Institute of Medicinal & Aromatic Plants, Lucknow generates least amount of funds (Rs. 3.4421 billion) and National Aerospace Laboratories, Bangalore spawns maximum funds (Rs. 50.1492 billion). Central Institute of Mining and Fuel Research, Dhanbad (Rs. 34.8753 billion), Indian Institute of Chemical Technology, Hyderabad (Rs. 28.4269 billion), National Geophysical Research Institute, Hyderabad (Rs. 27.9277 billion), National Environmental Engineering Research Institute (Rs. 26.8343 billion) and National Chemical Laboratory (Rs. 23.5373 billion) are the leading CSIR labs that gain utmost funds through commercialization of their technologies.

CSIR-NCL-GE Alliance in 1993 lead to 9 years of R&D collaboration which gained a cash flow around US $8.5 million over the period 1994-1995 to 2003-2004. GE even extended support to NCL- R&D with joined patents between NCL and GE. NALTECH Private Limited helps in commercialization and marketing of the technologies developed by NAL. Other CSIR labs are following comparable initiatives. A non-profit company- Entrepreneur Development Centre Ltd. (EDC), started in October 2006 by NCL under the name Venture Centre, helps NCL to commercialize its research and also provides incubator facilities to start-ups. To encourage transfer of technology, CSIR has started CSIR Tech Pvt. Ltd., with the aim of yielding spin-offs. CSIR Tech aims to develop products through independent private entity to support the conversion of technology to product.

Thus for effective transfer of science to technology, patent to license delays should be minimised. Value generation from IP to acquire extra budgets need to be focused on.

**Conclusion**

S&T interactions are highly diverse to be explained in a single matrix. S&T interaction can be assessed by studying the knowledge transfer process between scientific literature and its usage in advancement of technology. It is also very difficult to assess the knowledge transfer due to human interaction with external environment and it cannot be measured, only by the discussed
approaches\textsuperscript{76}. The human being shares data in various ways with his surroundings. Despite the limitations of these "direct" linkage approach such as incomplete databases, skewed distributions of non patent references, the complexity of cleaning and handling the data involved, using combination of these approach still offers enough evidences for analysing the S&T interplay given its considerable scope and quality of information\textsuperscript{77}. In other words, both empirical and qualitative research approach is required for performing a better analysis.

The next chapter analyses the question whether to patent or publish. Academic research is focused on scientific interest, popularly known as basic research. The whole focus is to disclose scientific and technical knowledge. Most of the basic research ends up in publications. Where in the applied research conducted in the companies is normally intends monetising the innovation outcome so as to increase the company market value. The research outcomes are patented and along with protection of trade secrets. There is always a dilemma in the minds of the researcher whether to patent or publish.


\textsuperscript{77} Verbeek et al., \textit{Linking science to technology: Using bibliographic references in patents to build linkage schemes}. Scientometrics 543: 399-420 (2002).