Knowledge Flow From Government R & D Institutions To Private Sector Industry And Its Role In Value Addition

Yogesh Suman

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ISTIP (Indian S & T and Innovation Policy): First Study of its kind focusing on various dimensions of innovation activity in India; aiming at providing valuable inputs for S & T and Innovation decision making.

Commercialization of scientific knowledge (generated in Government research or R & D[#] institutions) by developing industrial applications is absolutely crucial for taking benefits of research to society. However following may be kept in mind while attempting this:

- *Industry may not be interested in all the frontiers of science, therefore Government R & D institutions should not give up research in areas which are important for societal development even if they fail to attract industrial investment*
- *Industry is mostly interested in short term commercial gains, so while collaborating with industry enough care should be taken so that long term objective of knowledge generation through research is not compromised*
- *The path travelled by scientific knowledge before being converted into commercial industrial application is often long and unpredictable; therefore doing a cost benefit analysis of Government funded research is tricky and may prove to be infeasible.*

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1. Introduction

Knowledge[1] in any form is for the benefit of all living beings. Plato[2] defined knowledge as "Justified true belief". The basic objective of knowledge whether philosophical, scientific, technical or any other; is to make life better. By the very nature of it 'knowledge' is considered to be abstract-something which is dimensionless, can't be seen or touched but it expresses itself into objects and actions which are concrete, visible, can be touched and used for some purpose. Everything created by man is the result of some underlying knowledge, a physical expression of knowledge.

Scientific knowledge is the basic knowledge accumulated by systematic study of observable phenomenon and organized by general principles. This scientific knowledge can be applied to develop practically useful applications. But the path scientific knowledge travels before being converted into practically useful application is often long and rather unpredictable. E.g. heating effect of current was discovered by James Joule without any thought or imagination that one day Thomas Edison will use it to produce electric bulb or when Bernoulli coined his principle of fluid dynamics he had little idea that Wright Brothers will use it for making airplane someday in future. Despite all the uncertainties commercial exploitation of scientific knowledge by industry has been taking place quite regularly. In last one century or so the scientific research has become more organized with establishment of public funded research institutions by

[1] Oxford English Dictionary defines 'knowledge' as expertise, and skills acquired by a person through experience or education; the theoretical or practical understanding of a subject; it is also referred to as an aggregation of what is known in a particular field-in total; awareness or familiarity gained by experience about a fact or situation.

[2] Ancient Greek philosopher and mathematician who established first institution of higher learning in the Western world.

[#] R & D - Research and Development

various Governments all over the world, before that the research activities were result of individuals' zeal and efforts without any or little support from the state. Since Government money has been put into funding of research, often questions are asked on the returns in terms of money that may be earned from Government funded research.

In last few decades advent of globalization and falling trade barriers have enabled consumers to choose from a variety of products available at their door steps resulting in an increased competition among private sector industry. This has forced industry to either continuously develop new products or improve upon existing products, technologies and processes in order to be successful in marketplace.

This changed business scenario has increased the importance of research based scientific knowledge being generated in Government research institutions and the important role it can play in the industrial production process and services; giving rise to the concept of knowledge economy. Since Government research institutions are constantly involved in the process of knowledge generation, industries all over the world are now trying to exploit the knowledge base resulting from their (Government research institutions) research activities. Government research institutions can also generate income by selling their scientific knowledge to private sector companies.

Therefore flow of research based scientific knowledge from Government research institutions to private sector industry and its commercial exploitation by the latter is imperative for both. This policy bulletin talks about the flow of scientific knowledge that can be converted into a technology[3] and used by the industry for the production of commercially viable products. It talks about the factors and barriers which play crucial role in overall process of knowledge flow, effective management of which can tremendously increase the probability of achieving successful knowledge flow from Government research institutions to private sector industry.

Past experience shows that it is almost impossible to recover all the expenses of Government funded research through commercialization. Even in the most developed countries where Government has put strong emphasis on research commercialization through industrial application much before India, the most successful attempts of research commercialization has not resulted in huge commercial gains; but it has really helped in converting the fruits of scientific research into tangible form and taking them to the society. This latter part should be given more importance while pursuing research commercialization through industrial application.

So far a very small portion of scientific knowledge created in Government research institutions is able to reach private sector industry. Government research institutions are mostly engaged in basic research and their research activities are aimed at advancement of a discipline or a subject

[3]Technology is that knowledge which can be used to produce something for which there is a need(Hayek: 1941)

without any immediate practical/industrial application or use in mind.

2. Infrastructure for science commercialization-Government initiatives

Government put a lot of emphasis on establishing infrastructure for scientific research during initial days of Independence. This is reflected in 1958 Scientific Policy Resolution (SPR) of Government which states "to foster, promote and sustain the cultivation of sciences and scientific research in the country and to secure for the people all the benefits that can accrue from the acquisition and application of scientific knowledge". The period from 1950s and 1960s saw a lot of Government funded research institutions coming up. As per the directory of research institutions published by Department of Science and Technology (DST) in 2010, there are 4288 research institutions in the country which are classified into state sector, central sector, university, public sector and private industry. This science push was based on assumption that new technologies will emerge from basic science research. As a result a sufficiently large infrastructure for scientific research in the country has come up. Government also set up institutes like National Research Development Corporation (NRDC) in 1953 to act as catalyst in successful commercial exploitation of indigenously developed scientific knowledge.

Highlighting the need for increased technology capability of the country the Technology Policy Statement was released in 1983 by Government of India emphasizing the need for the development of indigenous technology to achieve technological competence. A lot of effort has been put in by Government since early 1980s to achieve the commercialization of the scientific knowledge being developed in Government research institutions. DST has established National Science & Technology Entrepreneurship Development Board (NSTEDB) to encourage knowledge driven and technology intensive enterprises. Innovation and Entrepreneurship Development Centre (IEDC) was established as a component of NSTEDB to expand institutional mechanism to generate entrepreneurial culture in academic institutions to further the growth of innovation and entrepreneurship amongst the faculty and students. Science & Technology Entrepreneurship Development (STED) scheme was also launched under NSTEDB with the objective to map the material resources in industrially backward regions and prepare some technically and economically feasible projects. As a third component of NSTEDB, Science & Technology Entrepreneurship Parks (STEP) are established to accomplish interface between academic institutions and industries for the development of commercially viable technologies. Other initiatives of DST involve Technology Business Incubators (TBI) to facilitate speedy commercialization of scientific knowledge. Working in the same direction Department of Scientific and Industrial Research (DSIR) has launched Technology Development and Demonstration Program (TDDP) to reinforce the linkages between industry, R&D establishments and academic institutions through the conversion of innovative ideas

into full fledged industrially commercialized products or services.

Apart from these, major scientific and academic agencies have also set up their own divisions to facilitate and expedite commercialization of scientific knowledge being generated out of their research work. E.g. Antrix established by Indian Space Research Organization (ISRO) works to promote and commercialize products resulted from ISRO's research and to provide technical consultancy services; Centre for Scientific and Industrial Consultancy (CSIC) acts as a bridge between academia at IISc Bangalore and industry; Foundation for Innovation and Technology Transfer (FITT) of Indian Institute of Technology Delhi has been acting as industrial interface of the institute; Sponsored Research & Industrial Consultancy (SRIC) of Indian Institute Technology, Kharagpur acts as an interface between funding agencies and the IIT Kharagpur; Biotech Consortium of India Limited (BCIL) is promoted by the Department of Biotechnology for speedy commercialization of scientific knowledge in the area of biotechnology; Society for Innovation and Entrepreneurship (SINE) at IIT Bombay works for promotion of entrepreneurship and commercialization of technologies based on the scientific knowledge developed by faculty and students at IIT Bombay. It has a business incubator to support technology based entrepreneurship, thereby extending the role of IIT Bombay to convert their research based scientific knowledge into entrepreneurial ventures. Similarly Council of Scientific and Industrial Research (CSIR), one of the country's largest public funded research organization having a vast network of some 38 research institutions; has also established infrastructure for commercialization of scientific knowledge being generated in its research laboratories. It has established technology networking and business development division (TNBD) to oversee and promote technology transfer and utilization of knowledgebase being generated in CSIR institutions all over the country. CSIR also took a big initiative of establishing CSIR-Tech in 2011, a private company which is deeply engaged in commercializing the technologies emanating from public funded research institutions. Apart from these almost each institution working under CSIR has its own division dedicated to commercialization of scientific knowledge being generated in that particular institution.

The Science and technology policy statement of 2003 has also put a special emphasis on technology development, transfer and diffusion.

3. Conversion of scientific knowledge into commercially viable technological products-crucial factors and barriers

Scientific knowledge generally passes through various stages (as shown in figure 1) before it turns up into a commercially viable technological product.

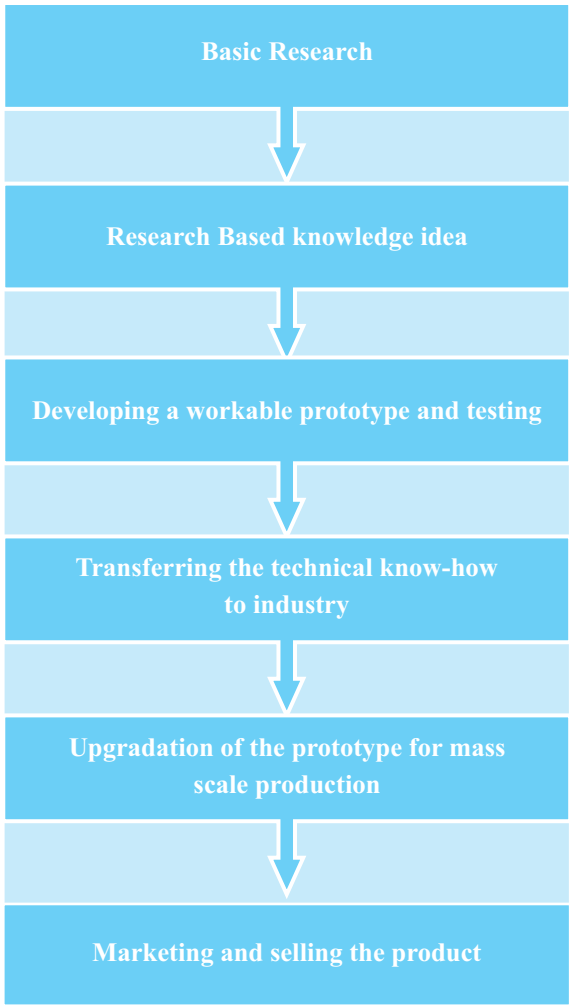

Figure 1: Conversion of scientific knowledge into commercially viable technological product

Flow of scientific knowledge based technologies may take place in horizontal or vertical form. Horizontal form refers to replication of technology used in one place, organization or context to other place, organization or context; whereas vertical form refers to the conversion from basic research to applied research, from applied research to development, and from development to production.

It may be formal when achieved through technology licensing and paying royalty/license fees or may be informal when achieved through observations, reverse engineering, publications or embodied in skilled people moving from one place to another.

For a particular scientific knowledge generated in Government research institution to be successfully converted into commercially exploitable technology, and transferred to a private sector industrial unit, following flow of events generally takes place:

- The concerned Government research institution and private sector industrial unit have to come in contact with each other and agree to work together.
- Technology development and testing process
- Transferring the technology to the industrial unit
- Up-gradation of the technology and mass scale production by industrial unit
- Selling the product

There are many factors which play a crucial role for successful completion of above process at different stages. These are explained as below:

1) **The Project initiation stage:** A particular project can be initiated either way- industry may approach a Government research institution with the requirement and the scientists in the institution starts working on it right from the scratch using their basic research results; or the industry comes to know about the already developed

scientific knowledge having commercial potential. This 'coming together' of a Government research institution and private sector industry is the foremost thing in the entire process of knowledge flow to take place. Following factors play crucial role for this 'coming together' to happen:

- Motivation level in industry to approach Government research institutions for technology or vice versa
- Level of networking between Government research institutions and industry
- Information about potential technologies available with Government research institutions
- Promotional schemes for approaching Government research institutions
- Level of focus by Government research institutions to develop technology for industry

2) **Technology development stage:** Once the project is initiated the process of developing the technology gets under way, the success about how far the technology is able to meet the industry requirement depends upon following factors:

- Industry's involvement in technology development process at Government research institution
- Level of communication between technology development team at Government research institution and the private sector industrial unit
- Resources availability for conducting field trials of technology
- Procedural hurdles in Government research institutions

Functional, cultural and perceptional barriers:

- *Scientists may think that developing short term solutions for industry can distract research from achieving its the long-term objective of new knowledge creation*
- *Industry may see scientist as someone sitting in 'ivory tower' only familiar with theoretical aspects of knowledge(having very little idea about industry dynamics)*
- *Scientists' objective of research is advancement of knowledge without having an immediate industrial application in mind*
- *For industry the only objective is to earn profit*
- *For industry the stakes are high but for scientist, it may be just another project*
- *For industry meeting deadlines is very important; while scientists see research as a long term process aimed at generating knowledge which might skip some short term deadlines*
- *Performance appraisal mechanisms in Government research institutions are heavily biased in favor of research publications*
- *In industry performance is judged on the basis of commercial profit earned by an individual*

3) **Technology Transfer and up-gradation for mass scale production stage:** Once the technology is ready, it is transferred to the industry and the industrial unit receiving the technology upgrades it for mass scale production. The successful transfer and up-gradation for mass scale production depends upon the following factors:

- Technical support from Government institution in the post transfer phase
- Availability of funds to assimilate and adopt the technology at the firm level
- Awareness about Government laws and regulations with regard to the technology acquisition
- Availability of funds to buy the technology developed in Government research institution
- Clarity on sources of funds to buy the technology
- Availability of supplementary equipments and machinery
- Geographical distance between Government research institution and the firm
- Availability of raw material

4) **Marketing and selling stage:** Once the product is ready. It has to be sold. Following factors may prove to be crucial for successful selling:

- Market readiness of the product developed using Government research institution technology
- Market potential of the product developed using the Government research institution's technology
- Support infrastructure(like transport, power supply, water supply)
- Availability of other similar kind of products in the market
- Funds to market the technology

4. Analysis and discussion

A careful handling of all these barriers and factors mentioned in the previous section can ensure successful flow of knowledge from Government research institutions to private sector industry. In any given project one or more of these factors may prove to be crucial for success or failure. Depending upon their nature these factors can be classified in five broad categories as below:

1) **Difference in outlook of Government research institutions and private sector industry towards each other:** This difference in outlook comes from the following reasons-

- Difference in objectives of Government research institutions and private sector industry
- Difference in work culture between industry and Government research institutions
- Attitude of Government research institutions towards private sector industry
- Apprehension among industry that Government research institutions don't understand industrial environment

- Difference in performance evaluation mechanisms between Government research institutions and private sector industry
- Level of focus by Government research institutions to develop technology for industry
- Difference in stakes and cost of failure
- Difference in time scales

2) **Coordination between Government research institutions and private sector industry:** Coordination depends upon following factors

- Procedural hurdles in Government research institutions
- Information about potential technologies available with Government research institutions
- Industry's involvement in technology development process at Government research institution
- Motivation level in industry to approach Government research institutions for technology or vice versa
- Level of communication between technology development team at Government research institutions and the team at private sector industrial unit
- Level of networking between Government research institutions and industry

3) **Commercialization of the technologies:** Successful commercialization depends upon the following-

- Market readiness of the product developed using Government's research institution's technology
- Technical support from Government institution in the post transfer phase
- Market potential of the product developed using the Government research institution's technology
- Resource availability for conducting field trials of the technology
- Availability of supplementary equipments and machinery
- Availability of raw material
- Availability of other similar kind of products in the market

4) **Financial resources:** This refers to the fund required to buy the technology and assimilating it at firm level; then to market it.

5) **Enabling environment:** Enabling environment refers to the prevailing atmosphere created by Government policies and infrastructural support. This mainly consists of-

- Support infrastructure(like transport, power supply, water supply)
- Promotional schemes for approaching Government research institutions
- Geographical distance between Government research institution and the firm

Important requirements for speedy and successful commercialization of scientific knowledge:

- *Strong, supportive & proactive leadership*
- *Continuous monitoring of technology development process*
- *Efficient production and marketing*
- *Tapping young entrepreneurs and SMEs*
- *Minimized procedural hurdles*

5. Policy suggestions

Science reaches the common man mainly in the forms of technological products; people might not be aware of heating effect of current but they surely are benefited by electric bulb. While it is absolutely important to make efforts for increased industrial application of scientific research emanating from Government research institutions, it has to be realized that industry might not be interested in all the frontiers of science, as their prime concern is commercial gains on investments. Therefore Government research institutions should not give up research in the other frontier areas of science not having immediate commercialization potential, just for the sake of developing industrial applications.

Another aspect to be kept in mind while pursuing research commercialization is that it is extremely difficult and mostly infeasible to do a cost benefit analysis of Government funded research, when and how a scientific research will result into a commercialized industrial application is very much uncertain. Application of heating effect of current to produce electric bulb looks straightforward but how much money and time went into discovery of heating effect and how much revenue was collected from production of electric bulb- this calculation might not be that straightforward. Therefore to look at it in purely 'cost benefit analysis' terms will be a rather unrealistic approach.

Past experience shows that it is almost impossible to recover all the expenses of Government funded research through commercialization. Even in the most developed countries where Government has put strong emphasis on research commercialization through industrial application much before India, the most successful attempts of research commercialization has not resulted in huge commercial gains; but it has really helped in converting the fruits of scientific research into tangible form and taking them to the society. This latter part should be given more importance while pursuing research commercialization through industrial application.

Government research institutions and private sector industry are two different worlds having different objectives, work culture, stakes and performance appraisal mechanisms. Therefore to achieve a successful research based collaboration between the two is a very challenging task. Following suggestions if implemented may help in successful commercialization of scientific knowledge through development of industrial applications:

Strong, supportive & proactive leadership and other initiatives:

- A strong, supportive and proactive leadership in Government research institutions is very first necessity to initiate research collaborations with private sector industry and commercialization of scientific knowledge.
- Scientists working in Government research institutions should be given sufficient exposure to develop proper understanding of industrial environment and people from private sector industry should also be given enough chance to know about the activities of Government research institutions.
- The information about scientific knowledge having commercial potential which are available with Government research institutions should be widely disseminated.
- Efforts should be made to develop networks between Government research institutions and private sector industry through exhibitions, seminars, workshops and field visits.
- Dedicated technology transfer offices(TTOs) should be established within Government research institutions having people with expertise like market and technology assessment, negotiations, technology licensing and intellectual property rights.

Continuous monitoring of technology development process:

- The process of technology development should be continuously monitored.
- Sufficient autonomy should be given to scientists in the Government research institution who are involved in the technology development process.
- Industrial unit should be involved in the technology development process.
- There should be clear and proper communication between technology development team at Government research institution and the private sector industrial unit.
- All the required resources should be made readily available without unnecessary procedural delays generally encountered in Government research institutions. Otherwise the technology might become obsolete even before it developed and introduced in the market.
- Technology should require minimum modification to go into production.

Efficient production and marketing:

- Proper planning and should be done to market the product.
- Prior assessment of the market should be done by the industrial unit before undertaking the technology development.

- Sufficient finance should be made timely available for mass scale production.
- Availability of raw materials should be checked, along-with dependency on import material of any kind.
- Technical support in post transfer phase should be ensured.
- Finance and expertise for establishing production plants should be made available easily and readily.
- The product should be able to compete with the already existing products in the market in cost terms.

Tapping young entrepreneurs and SMEs:

- Startup enterprises on research based technologies represent a huge opportunity for science commercialization. Government research institutions should look for young entrepreneurs who are aspiring to start new enterprises on research based technologies.
- Small and Medium Enterprises(SMEs) generally suffer from shortage of funds to fulfill their technological needs through technology imports, these SMEs can be hugely benefited through indigenous technologies developed in Government research institutions
- Recently Government of India has taken a lot of initiatives to promote start ups, reforms in labor laws, taxation, and ease of procedural hurdles in getting clearances for businesses. These initiatives should be tapped and used to convert scientific research into saleable products.

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For suggestions/feedbacks, please contact: yogesh.nistads@gmail.com

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