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The triple helix is considered an important concept because it not only advocates partnerships among government, industry and university/public research institutions, but it also claims (explicitly or implicitly) to provide strategy for innovation. The present study was undertaken in 2001 to understand the relevance of triple helix in the context of biotechnology in the National Capital Region of Delhi in India. The empirical research conducted through questionnaire and interviews was restricted to scientists from public sector research and academia. The analysis based on fieldwork data was also supported by secondary sources of information. The empirical findings reveal that bilateral linkages and partnerships—mostly between government and public sector research institutions, including universities—seem to be more relevant and meaningful than tripartite relationships. Even though scientists now do seem to be positively oriented to commercialisation of knowledge and accord high importance to it, they continue to assign equally high importance to publications compared to patenting. Our study reveals that scientists in universities and national research institutions lack adequate and effective institutional and organisational framework and mechanisms that foster commercialisation of knowledge. In conclusion, the study attempts to underscore some policy measures that will catalyse triple helix-based partnerships in context of biotechnology sector in India.

* Research reported in this article is part of an M.Phil. dissertation on the subject undertaken during 2000–2001 at the Centre for Studies in Science Policy, School of Social Sciences, Jawaharlal Nehru University, New Delhi.

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ALMOST ALL ANALYSTS now agree that linear models of basic research leading to application and technological innovation is over-simplistic and no longer to be followed and advocated by policy experts and decision makers. Sir Nicholas Fenn (British High Commissioner to India 1995) emphasised this point during the Indo-British Seminar on Industry–Institute Interaction in 1995 by citing Akio Morita's (chairman of Sony Corp.) title for the first UK innovation lecture: '"S" Does Not Equal "T" and "T" Does Not Equal "I"' (Fenn 1995).[1] Although of late it has been realised that getting wealth without systematic knowledge is not an easy and straightforward affair, at the same time the majority would agree that getting wealth from knowledge is not particularly easy either (if that had been the case, all professors would have been millionaires!).

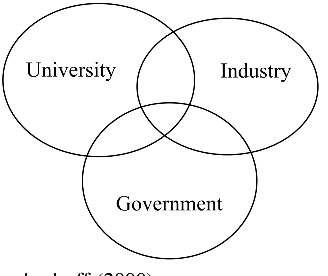
The production of knowledge has undergone a change over the years and this has been both of concern and as well interest to people from various disciplines, from philosophers, and historians to sociologists and economists. Science policy analysts are typically interested in the empirical evidence either for the new trends to be identified or to prove that the trends seen are not anything new in order to be better informed to make better decisions. This has led to quite a lot of interest to study so called 'move towards a knowledge-intensive society', wherein academics face pressure to link their work more closely to the needs of economics and society. Guston and Keniston (cited in Martin 2001) refer to this as a fundamental change in the 'social contract' between science and the university on the one hand, and the state on the other, with the latter now having much more specific expectations regarding the outputs sought from the former in return for public funding. It is stronger international competition that led to the notion that the key to success lay in continuous innovation to improve productivity and competitiveness, and so the imperativeness for nations to use science as strategic competitive resource (ibid.). But at the same time, as governments across the globe have experienced greater budgetary constraints due to increase in various expenditure (especially due to demand in more social securities), there has been a focus on accountability and better value for money for everything, including expenditure on R&D (ibid.). An integrated and interactive approach blending scientific, technological, socio-economic and cultural aspects is required to explain the dynamics of innovation (Conceicao et al. 2000). It is, thus, seen that non-linear models that analyse the developments in terms of networks have superseded linear models of innovation.[2]

Within the broader domain of non-linear innovation models, a lot of new terms and concepts (like 'mode 2', 'national innovation systems' and 'triple helix') have been proposed by various philosophers. Most of the concepts broadly refer to the earlier-stated phenomenon. This article intends, first, to discuss the status quo of the triple helix model of innovation, which is one of the proposed non-linear models, and widely used in policy discussions in a global context (with special reference to developing countries) in general, and then comment on its relevance to the Indian scenario based on empirical findings.

The Triple Helix Model of Innovation

Of the non-linear models of innovation, triple helix is considered to be the most evolving and dynamic. This model is a new framework for understanding and encouraging the innovation process. Triple helix reflects partnerships among university, industry and the government that lead to trilateral networks and hybrid organisations. The most popular variant of the triple helix model these days is known as the triple helix III (see Figure 1). In addition to it there are two other models, having their genesis in varying institutional arrangements developed in different cultures/ nations.[3]

FIGURE 1
Triple Helix III



Source: Etzkowitz and Leydesdorff (2000).

University, industry and government, as relatively equal partners, are identified as the key actors in creating new networks and hybrid organisations. The solution of the 'production puzzle'[4] typically brings the government into the picture, shifting the dynamics from a 'double' to 'triple' helix. Trilateral networks and hybrid organisations are created for resolving social and economic crises.[5] The actors from different spheres negotiate and lead to creation of new entities, such as venture capital firms, spin-off firms, technology incubators, science parks, etc. Thus, a triple helix dynamics of university–industry–government relation is generated endogenously (Etzkowitz 1998). There is no assumption of a fixed end point such as the development of market economy in this model. For example, the market is also a governmental instrument that assures the validity of contracts and the stability of transaction mechanism. The triple helix model takes the traditional forms of institutional differentiation among universities, industries and government as its starting point (ibid.). The model takes into account the expanding role of the knowledge sector in the dynamic process of growth through technological innovation. Hence, the role of partnerships between the three sectors is seen as crucial.

According to Etzkowitz and Leydesdorff (cited in Giesecke 2000), the triple helix model reflects that innovation is a spiral movement that captures multiple reciprocal relationships among institutional sectors (public, private and academia) at different stages in the capitalisation of knowledge, and thereby changes knowledge-producing institutions. The four processes related to major changes in the production, exchange and use of knowledge, which the triple helix model puts forward are: (*a*) internal transformation in each of the helices; (*b*) influence of one institutional sphere upon another in bringing about transformation; (*c*) creation of a new overlay of trilateral linkages, networks and organisations among the three helices serving to institutionalise, reproduce and interface, as well as stimulate organisational creativity and regional cohesiveness; and (*d*) the recursive effects of these inter-institutional networks representing academia, industry and government, both on their originating spheres and the larger society (Etzkowitz et al. 2000).

Public Sector Research in Triple Helix

Since, public sector research, especially in universities, are considered to be the most important element of the triple helix model, it is imperative to discuss in brief the changes in the institutional character of university/public research to what Elzinga (cited in Etzkowitz et al. 1998) has called an 'epistemic drift towards measuring the utility of science in terms of criteria that are steered by market considerations'. Some of the more visible changes of this 'epistemic drift' are as follows:

1. The capitalisation of knowledge has replaced 'disinterestedness' (defined by Merton as the expectation that scientific knowledge

would be freely distributed with researchers taking their rewards in recognition from peer). This has led to a shift in the orientation of the academic and public research culture from being devoted exclusively to the research and training interests of professional staff towards being open to more entrepreneurial activity and receipt of private profit for the research that is being pursued (this could take various forms, like consultancy, equity in a company, spin-off firms, etc.).

2. The issue of management of intellectual property has gained prominence even in public sector research in recent years. The aforementioned reasons could also manifest into scientists being reluctant to publish their work fully and freely because of professional competition and commercial pressures.
3. A change in student, faculty and administration relations as students' best chances at jobs and as future carriers may lie in establishing their own company on the basis of their research (Etzkowitz et al. 1998), rather than going for an academic career or basic research.
4. There have been changes in the norms of reward structure related to scientific research primarily because of change in funding system.[6] This led to change in perception about the performance of research in terms of deliverables. Libert and Hackett (cited in Louis and Anderson 1998) hold a similar viewpoint and draw attention to change in assessment of performance, where in many fields the size and number of research grants have come to be recognised a 'quick and dirty' indicator of the disciplinary prestige.
5. Emphasis on the commercialisation of academic research has led to many structural changes in most higher education and research institutes. They have established agencies designed to exploit their own intellectual property. For example, technology transfer offices are being established that are either developed out of existing administrative units such as campus legal departments or are being formed as entirely new organisational structure.[7]

The Triple Helix as a Global Phenomenon

One of the vital elements of the triple helix is the strong linkage among university, industry and government. Most researchers have substantiated this claim of the growing affinity between industry and academia based on their research in developed countries, primarily the USA (Turpin et al. 2002). This growing body of research indicating the success of the triple helix in the USA had a wider impact in the S&T policy circle all round the globe (including developing countries) wherein public research (including academia) came under intense pressure to cooperate and develop strong linkages with the industry. Although Pavitt (2001) has a word of caution for policy makers and draws everyone's attention to the fact that:

> US practice vis-à-vis basic research has been misinterpreted as being driven by short-term usefulness catering to industrial needs, whereas infact its key features are massive and pluralistic government funding and ability to invest in the long-term development of new fields (p. 761).

He substantiates his claim further by quoting Geuna, who states that, 'although the share of business firms in the funding of academic research has increased in most OECD countries over the past ten years, it remains below 10 per cent and government funding remains predominant (ibid.: 767),' and that, 'the proportion of university research that is business-financed in the USA is smaller than in most European countries' (ibid.: 767). Pavitt (ibid.) further extends his observation.

> Successful US practice in exploiting new science-based technologies has often been interpreted as a consequence of the higher market orientation of universities, but strikingly this achievement is based on research and institutions that are ranked highly by purely academic standards (p. 761).

He suggests that even two most recently successfully industrialised countries, Taiwan and Korea, have been able to strengthen their knowledge base because of huge government spending in building R&D infrastructure. Juma et al. (2001) also subscribe to this viewpoint.

Sutz (1998) draws upon a number of articles presented during the Triple Helix Conference II to stress the need for intense government involvement in basic research. It is worth to discuss a few examples cited by Sutz that emphasise the validity of bilateral linkages between public research and government over much-hyped trilateral linkages. Australia has very successfully implemented cooperative research centres, especially in the biomedical field, that link private firms with public research, and this has been brought about primarily by government initiative and funding. Engineering research centres (ERCs) created during mid-1980s in the

USA were primarily created by a government agency—the National Science Foundation (NSF)—which is largely devoted to basic research, by a multi-million-dollar investment. The industry got involved mainly because there was need for the knowledge generated out of the basic research and the industry could make use of it by paying only minimal fees. The Brazilian National Software Export Program (also called Softex 2000) is also an initiative owed to the Brazilian computer science community that is being funded by the National Research Council, an entity of the Ministry of S&T. Sutz (1998) also quotes a research by Casas et al. that reveal that initiatives in Mexico in biotechnology, new materials and telecommunications are primarily developed by the government to support networking and, thus, increase the performance of triple helix modalities.

While studying the introduction of the incubation system in Algeria, Saad (2004) reflects upon the difficulties in implementing innovation strategies based on the triple helix model in developing countries because of lack of power and capability of one of the key actors to contribute effectively; this is apart from various other inhibiting factors like organisational structure and historical milieu. Juma et al. (2001) are of a similar view that in developing countries, where private venture capital is not well developed, governments have to take the lead and directly support such initiatives. Indeed, the Chile Foundation, an initiative by the Chile government, is credited with the identification and development of technologies that are of relevance to the Chilean economy (for example, salmon farming) (ibid.).

Apart from these factors, the new global IPR regime also inhibits the strengthening of innovation systems in developing countries, thus, inhibiting developmental benefits accruing to the concerned country (ibid.). For example, according to the WHO only eleven out of 1,223 new chemical entities developed between 1975 and 1996 were for the treatment of tropical diseases, and for even these the majority of research was performed either by international organisations or by the military in industrial countries because pharmaceutical firms are discouraged to perform research related to drug needs of developing countries due to prohibitive costs and low margins of profits (ibid.). This is, thus, another stumbling block to the wider acceptance of triple helix as an innovation model because governments in developing countries perforce have to fulfil the developmental needs of society. For example, the South African government supports various national and international public research institutes that are part of a 'bioprospecting consortium' because private industry and venture capital initiative is minimal (ibid.). Similarly, the Chinese government has directly supported biotechnology initiatives that increase yield and reduce use of expensive pesticides, thus benefiting poor farmers. Example, Monsanto's Bt Cotton is now extensively cultivated in China, 87 per cent of financial savings of which has gone to farmers, 8 per cent to Chinese seed companies and only 4 per cent to Monsanto (ibid.).

Based on these observations, this article empirically looks into the postulate by Turpin et al. (2002) that developing countries require quite different policy instruments from developed countries. It also takes into consideration the cautionary note made by Pavitt (2000) about the generalisability of the dominant thought that industry shall increasingly drive social and economic developments with minimal government intervention. Both thoughts are also in keeping with observations by a few scholars from developing countries, like Krishna et al. (2000), that there is a need for new networking strategies in developing countries as the proposed new non-linear models of innovation (like mode 2) will leave developing countries even more vulnerable than in the past.

The Present Study

The modern biotechnology sector is designated as a high-tech industry where companies spend a large amount of funds on R&D programmes, both national as well as transnational, to enhance the development and commercialisation of biotechnology products. Also, faced with turbulent environments and global businesses, collaboration has become a common way to organise economic activities. This seems to be more important for high-technology industries (like biotechnology)[8] with inherently high uncertainty and complex business environment.

More recently in India the business environment became all the more turbulent (and is set for major changes) due to India signing Trade Related Intellectual Property Rights (TRIPS) in 1995, after it joined the WTO. This meant that India had to bring about major changes in its patent laws, and probably the industry segment that was to be most seriously affected was to be life sciences. India was given ten years to bring changes to its national laws to be in accordance with TRIPS.

Until then the Indian Patent Act of 1970 had allowed only process patents to be granted in India. This had its both positive and negative effects. On the positive side, it led to the growth and development of indigenous industry because they could afford to invest meagre amounts in reverse engineering and still come up with a product at a cheaper price.[9] On the negative front, the industry became more reliant on short-term research, and made little effort to bring 'new' products (that is, new to the world) to the market. And, hence, the industry never bothered to invest in 'serious' R&D. Ramani (2001), while exploring the pharmaceutical industry (and based on data till 1994), came up with a conclusion that most firms were simply marketing products or producing a biotech-based product using a licence; hence, their capacity for drug discovery was rather limited.

So the change to 'product' patent (by the start of 2005) became imperative because of India signing TRIPS. This was a major change for life sciences-related industry (that is, both pharmaceutical and agriculture). They would now be forced to develop their own products and be competitive. This would then mean that they had to develop their R&D capabilities to world standards, for which they have been given ten years (starting 1995 till 2004 end). One important way in which Indian industry could think of developing it was to build the R&D capability in-house, partner with public sector research and academia; and a mix of both.

India signing TRIPS can be said to be a historic and defining move. It had the ability to bring about structural changes in a particular industry, the life sciences industry being no exception. In a way this step taken by the government in 1995 can be seen to lead to changes similar to that of the Bayh-Dole Act of 1980 in the USA. Following this act, public–private partnerships involving various research institutions, universities and companies evolved to bundle competencies and facilitate technology transfer in USA. These partnerships often were initiated or promoted by the government. This was especially the case in life sciences. Some of the main features that drove the biotechnology industry in particular towards collaboration were: high expenditure in research, global competition, public interest and commercialisation of basic research. These insights, coupled with the discourse on university and industry partnerships in India, led to the present study.

The Bayh-Dole Act had attracted a lot of research interest on its impending effects. Many research articles have been written over a period of time (and are still being written) that systematically analyse the effects of it on various industries. Similarly, the evolution of such transformations in other countries (like the UK, France and Germany) has also drawn the interest of many researchers. But, surprisingly, it is hard to find any such study vis-à-vis India.[10] It will then be important and quite useful to study the effects of this TRIPS agreement (on various dimensions and on various industries). The most suitable way could be to document the evolution of its effect in a chronological order.

This empirical study was driven by following set of objectives:

1. As mentioned earlier, science policy analysts are typically interested in the empirical evidence for new trends in order to be informed to make better decisions. Thus, the most important agenda of this study was to explore the relevance of the concept of triple helix within the biotechnology sector in the Indian context. The study not only informs policy makers of the present scenario, but can be used to see any changes occurring in the future due to new policy measures being institutionalised by the government of India because of its commitments to the WTO.
2. Given the centrality of linkages between the three helices in the concept of the triple helix, the study explores the linkages between three different actors in the biotechnology sector. The exploration of linkages is mapped through the funding patterns of projects in evolving partnerships; and the structure of orientations of projects as perceived by scientists selected in the sample. Given the limitations (of time, scope and resources), the objective of mapping linkages of the industry component has been examined through the university and public sector research institutions only. In other words, the role and influence of industry has been explored to the extent it is manifested in the earlier two components: funding pattern of projects in public research institutes, and perceptions of scientists in public research institutes.
3. Given the importance of transformation of each of the helices, this study explores the extent of institutional and organisational changes that are taking place in academic and public sector research institutions in the biotechnology in the Delhi region. An effort has also been made to explore the orientational changes of professionals in academic and public sector research (with respect to commercialisation of science versus 'academic' orientations).
4. To what extent does the concept or idea of the triple helix find its relevance as an innovation strategy in the Indian context and in what form? Given varying manifestations of triple helix in national contexts, this question is considered one of objectives of the study from the point of S&T policy studies.

Research Methodology

The research design selected had components of both the exploratory and the descriptive/diagnostic. It can be said to be exploratory because it has elements like non-probability sampling design;[11] the research tries to shed new insights into the problem; and it intends to chart new horizons in scientific explorations, advance, and test new principles of procedure and suggest new concepts. The components of descriptive/diagnostic are: pre-planned design for analysis; and structured instruments for collection of data (namely, questionnaire and semi-structured interviews along with secondary sources) that is rigid but with enough provisions to protect against bias and maximise reliability.

The research is based both on quantitative data as well as qualitative data as mentioned previously. Since this research tries to explore various research questions (previously mentioned) related to university, industry and government partnerships in the biotechnology sector in the Delhi region[12] from perspective of public sector research, it was imperative to first determine the institutes where fieldwork was to be carried out. For this, it was decided to rely on report by Department of Biotechnology (DBT), Ministry of S&T, of the Indian government which provided a list of technology transfers that were carried out by it from various institutes to a company (thus, reflecting concrete university–industry–government partnerships). This led to four premier public research institutes from Delhi being involved: the National Institute of Immunology (NII), Centre for Biochemical Technology (CBT),[13] All India Institute of Medical Sciences (AIIMS) and Delhi University (DU). It was decided to include the Indian Institute of Technology, Delhi (IIT, Delhi), National Plant Biotechnology and Genetic Research Institute (NBPGR)[14] and Jawaharlal Nehru University (JNU) because all of them are coveted institutes having biotechnology/life sciences departments that are highly reputed for their research outputs.

After selecting the institutes, the next important step was to identify scientists/professors in each of these from whom data was to be collected. For this latest annual reports from each of the institutes were collected. From these reports the project leaders/professors involved in biotechnology[15] projects (and not any bio/life sciences project) were identified.[16] Thus, the sample that was taken was not based on random sampling, but was purposive in nature.

The quantitative data was obtained by questionnaire that was administered to each of the project leaders/professors identified.[17] In total fifty scientists/professors were identified in the seven institutes. Questionnaires were distributed to them. Twenty-eight people responded, that is, the response rate was 56 per cent. These scientists were asked to respond on various ongoing projects of their own, which were in operation for the three years (1999–2000, 1998–99 and 1997–98) that preceded this study. The scientists reported seventy-four projects in all.[18] After having gathered data by questionnaire, it was decided to go for semi-structured interviews with a few of the scientists in order to further explore and gain insight into the complexities of the problem reflected by the data that was gathered. This qualitative exploration by interviews led to giving more credence to the quantitative data.

Empirical Findings

Funding of Projects in Public Research Labs

The sources of funding for research projects reveals to a large extent the commercial relevance of projects and orientation of researchers. In various studies the funding pattern of research is taken as a parameter or indicator to understand the orientation of institutions and researchers. Mansfield (1995) in his seminal work used 'the amount of funding' to establish the level of public–private partnership in five different industries in the US.[19] Boyd and Bero (2000) had used 'the number of projects' approach to assess financial ties between academic researchers and private industry.

Our study indicates that Government of India (GOI) through the Department of Biotechnology (DBT), Department of Science and Technology (DST) and other government agencies like ICAR, CSIR, UGC, CPCB and DRDO are funding bulk of the projects (83.8 per cent) in universities and national laboratories.[20] Industry was found to be involved in just 8.1 per cent projects. Even the individual break-up reflected the same trend (that is, maximum projects being funded by the GOI) in almost all the institutes (universities and national laboratories) covered under the study—DU (76 per cent); IIT (62.5 per cent); CBT (100 per cent); AIIMS (75 per cent); JNU (84.6 per cent); NBPGR (100 per cent); and NII (100 per cent) (Table 1).

Even an attempt to understand orientations by taking note of break-ups of actual amount of funds involved in R&D in public sector research (that is, government laboratories and universities) under sponsored or collaborative projects reflected that a very high proportion (78 per cent) of the funding was by the government (Table 2).[21] And the projects in which funding was solely by a company accounted for a mere 2.2 per cent of the total funding pattern. Proportion of funds involved in projects, which were sponsored jointly by government and foreign institutes/agencies (like the World Bank or European Union) or solely by foreign agencies

TABLE 1
Sources of Funding to Projects in Different Biotechnology Institutions in Delhi Region

Institutes	*Government funded*	*Industry funded*	*Others**	*Total*
AIIMS	3 (75%)	0 (0%)	1 (25%)	4
CBT	10 (100%)	0 (0%)	0 (0%)	10
DU	19 (76%)	3 (13%)	3 (13%)	25
IIT	5 (62.5%)	3 (37.5%)	0 (0%)	8
JNU	11 (84.6%)	0 (0%)	2 (15.4%)	13
NBPGR	8 (100%)	0 (0%)	0 (0%)	8
NII	6 (100%)	0 (0%)	0 (0%)	6
Total	62 (83.8%)	6 (8.1%)	6 (8.1%)	74

Source: Sardana (2002).
Note: *Others include foreign bodies like the European Union, Indo-Swiss cooperation and Indo-US cooperation.

TABLE 2
Actual Financial Support for Biotechnology Projects (Rs million)

Institutes	*Government*	*Industry*	*Industry + government*	*Others* + government*	*Others*
NII	7.4 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
NBPGR	30.7 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
JNU	19.5 (78.25%)	0 (0%)	0 (0%)	0 (0%)	5.42 (21.75%)
AIIMS	1.0 (83.33%)	0 (0%)	0 (0%)	0 (0%)	0.2 (16.67%)
CBT	7.15 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
IIT	8.94 (22.7%)	0.42 (1%)	30 (76.3%)	0 (0%)	0 (0%)
DU	59.893 (67.4%)	3.3 (3.7%)	6.9 (7.8%)	8.6 (9.7%)	10.1 (11.4%)
Total	134.583 (78%)	3.72 (2.2%)	9.9 (5.7%)	8.6 (5.0%)	15.72 (9%)

Source: Sardana (2002).
Note: *Others include foreign bodies like the European Union, Indo-Swiss cooperation and Indo-US cooperation.

was approximately 14 per cent (5 per cent and 9 per cent respectively). Even the break-up of funding in terms of real investments within individual institutes reflect that in almost all of them (except IIT) the proportion of funding accounted solely by the government or its agencies was greater than 70 per cent. This in itself shows the level and direction of partnership in India.

Orientation of Projects in Public Research Labs

Quite surprisingly, it transpired that the majority (64.8 per cent) of projects had some relevance (either direct or indirect) to industry (Table 3). Projects of direct industrial relevance constituted 32.4 per cent, indirect industrial relevance comprised 32.4 per cent and of academic relevance were 36.2 per cent of the total projects.[22] In other words, even though the majority of projects received government funds, they had considerable relevance to industry in the perception of public sector research scientists. The break-up percentage of projects of specific type of relevance in individual institutes varies and does not show a uniform pattern, but a close look revealed that the percentage of projects showing any relevance (direct or industrial) to industry in different institutes (like, Delhi University 68 per cent, CBT 70 per cent, JNU 53 per cent and NBPGR 75 per cent) are to a large extent in keeping with the cumulative figure (64.8 per cent).

Table 3
Type of Relevance of Biotechnology Projects

Institutes	*Direct industrial*	*Indirect industrial*	*Academic*	*Total*
AIIMS	0 (0%)	1 (25%)	3 (75%)	4
CBT	5 (50%)	2 (20%)	3 (30%)	10
DU	8 (32%)	9 (36%)	8 (32%)	25
IIT	5 (62.5%)	3 (37.5%)	0 (0%)	8
JNU	3 (23.1%)	4 (30.8%)	6 (46.1%)	13
NBPGR	3 (37.5%)	3 (37.5%)	2 (25%)	8
NII	0 (0%)	2 (33.3%)	4 (66.7%)	6
Total	24 (32.4%)	24 (32.4%)	26 (35.2%)	74

Source: Sardana (2002).

Orientation of Scientists in Public Research Labs

This study also tries to reflect upon the shift in the orientation of the academic and public sector research culture, from being devoted exclusively to research and training interests of professional staff towards being open to more entrepreneurial activity.[23] Table 4 shows, that exploration and adding to systematic knowledge is still high on the agenda of public sector research scientists, as 96.4 per cent say that this is important for them. This reflects that the traditional value and importance of basic research has still been very much retained. But this inertia to remain fixed to 'basic' research seem to be breaking as more and more scientists are now open to the idea of capitalisation of knowledge because of growing demand and respect for public accountability for research that are carried out by tax-payers' money. Seventy-five per cent of scientists say that designing of products is important to them and almost the same percentage (71.4) say that solving a problem for a client/industry is important.

TABLE 4
Importance Attached to Each Step in the Process of Capitalistion of Knowledge

	High importance	*Medium importance*	*Low importance*
Exploration and adding to systematic knowledge	27 (96.4%)	1 (3.6%)	0 (0%)
Patenting	14 (50%)	12 (42.9%)	2 (7.1%)
Design of products/kits	21 (75%)	4 (14.3%)	3 (10.7%)
Solving a problem for a client/industry	20 (71.4%)	3 (10.7%)	5 (17.9%)

Source: Sardana (2002).
Note: A 5-point Likert scale was used. Here, for convenience, 5 and 4 in the Likert scale have been taken as 'high importance', and 1 and 2 as low importance.

Researchers, as shown in Table 5, seem to be very keen to collaborate with industry for commercial gains out of their research, with 95.45 per cent of scientists saying that they give high importance to sharing new product ideas with industry. Quite expected and in tune with the data, 86.36 per cent of researchers are keen to collaborate with industry to develop new products/process technologies. Apart from this, a majority of scientists are not averse (in fact, give a high rating) to other channels by which industry could look forward for collaboration—feedback on existing products/processes (72.73 per cent), new R&D procedures/methodologies (72.73 per cent), and developing skills in experimentation and

TABLE 5
Level of Importance to Ways of Interacting with Industry*

	High importance	*Medium importance*	*Low importance*
New product ideas	21 (95.45%)	0 (0%)	1 (4.55%)
Feedback on existing products/processes	16 (72.73%)	2 (9.09%)	4 (18.18%)
Routine Problem Solving	10 (45.45%)	5 (22.73%)	7 (31.82%)
New Research Equipments	9 (40.91%)	7 (31.82%)	6 (27.27%)
New R & D procedures/methodologies	16 (72.73%)	4 (18.18%)	2 (9.09%)
Skills in experimentation & testing	14 (63.64%)	7 (31.82%)	1 (4.54%)
New Product/Process Technology	19 (86.36%)	3 (13.64%)	0 (0%)

Source: Sardana (2002).
Notes: The 5-point Likert scale was used. For convenience, 5 and 4 have been taken as high importance, and 1 and 2 as low importance.
*The idea was derived from the list of 'Impact of STI to Innovation' prepared by Faulkner and Senker (1995). Some changes were made to adapt the question in the questionnaire to the research need and for it to be suitable to an Indian context.

testing (63.64 per cent). Only 45.5 per cent of respondents give importance to routine problem solving. However, there still persists a good deal of stress by researchers on the traditional 'ethos of science' that relates to 'basic research'. Perhaps this might be the reason for which they give moderate importance to the 'not-so-intellectually-stimulating' routine problem-solving exercise. And another reason for lack of interest in this could be that generally industry seeks to solve its routine problems internally.

The change in orientation towards commercialisation of knowledge is so very significant that about 42.9 per cent respondent scientists in this study claim to have improved products/manufacturing process out of their research projects in the past, and almost everybody acknowledged their increasing administrative roles as fund raisers, personnel managers, publicity agents and research directors of a team of researchers.

Despite significant observations in the change in orientation of scientists, one important observation that comes to the fore from this research is that 88.9 per cent of scientists still believe that there is a conflict between commercialisation of research/patenting and publication. Also, 92.6 per cent of scientists still think that publishing in peer-reviewed eminent science journals is as important as commercialisation of knowledge. It has been noticed that it is mainly mission-based institutions that are taking the lead in changing to patenting mode. For example, during academic year 1998–99 ninety-eight research articles and papers were published in various journals from the School of Life Sciences and Centre for Biotechnology, JNU. This seems to be quite a big achievement by a single institute. But the faculty had been able to obtain only five patents till 2000. On the other hand, during 1996–98, scientists from the CBT were able to publish sixty-two research articles. And during the same period fourteen patents were filed. This ratio of publication to patenting by a single institute is really very impressive, given the Indian scenario. Similarly, from NII fifty-seven peer-reviewed research articles were contributed during 1998–99 and an impressive tally of nine patents were obtained in 1998–99.

IPR and Commercialisation Mechanisms

Institutions by their very nature regulate the relations between people and groups of people within as well as between and outside organisations. This means that institutional set-up affects the pattern and the content of communication and interaction in the economy. Since we regard innovation as mainly resulting from interactive learning processes, it follows that institutions affect innovations (Edquist and Johnson 1997). Analysis of the emergence of new forms of institutional structures thus becomes important as it can respond to the theoretical issues discussed earlier. For example, the institutional structure may steer/prohibit scientists towards setting up of research agendas that are commercially oriented. Indeed, the data seems to suggest so. About 50 per cent of scientists in this study feel that their institute gives due importance to commercialization of knowledge, but this statistic, when looked at on a micro level, brings out the fact that a very high proportion of scientists who have this positive opinion are from mission-oriented national labs, and relatively few subscribe to this from universities. When this is related to the organisational change that has taken place in institutes that were part of this study, it becomes evident that mission-oriented national labs (like the CBT and NII) had brought about more effective changes vis-à-vis universities. In this section we will discuss the steps taken and schemes initiated by the concerned institutes and government to enhance the level of cooperation between public research and industry.

Institutes in this Study

The NII does have a small department that helps scientists by guiding them in writing patents, educating them in patent laws, filing of patents, negotiating for transferring of technology, etc. It also has a very lucrative policy for scientists for commercialising their technology—scientists get the major share by transferring their technology or by royalty payments.

All CSIR labs including the CBT have optimised their structure to facilitate commercialisation of knowledge. The CSIR has centrally established two crucial departments, the Intellectual Property Management Division, and R&D Planning and Business Development Division. They have formalised a very lucrative policy for the income distribution for the wealth generated out of contract/collaborative research, advisory consultancy and in-house projects. From the income generated out of contract research and in-house projects that are commercialised, 40 per cent of total fees received is distributed among principal innovators (40 per cent of the 0.4x), S&T and other staff (35 per cent of the 0.4x), entire lab excluding the two mentioned categories (20 per cent of the 40 per cent) and welfare fund for scientists (5 per cent of the 0.4x). Similarly, for advisory consultancy, two-thirds of the amount obtained is distributed: 95 per cent of the two-thirds is given to the principal scientist or group, and 5 per cent is deposited as welfare fund.

But quite on contrary, AIIMS, JNU and DU have shown little progress in this direction. These institutes themselves have no specific departments that provide any help concerning transfer of technology to industry, writing of patents, filing of patents, etc. Scientists/professors in these institutes have to take their own initiative to approach the DBT, DST, National Research Development Council (NRDC) or any other government agency for help, and that often requires huge investments of their time. Though they have lately come up with lucrative policies for revenue sharing from the commercialisation of R&D work done in the university, without formalised structures like technology transfer offices, various other initiatives are not bearing any fruit.

IIT, Delhi, seems to be an exception among other academic institutes covered in the study. This can be attributed to the fact that the charter of the IIT in itself has a mandate for industrial consultancy in engineering and technology along with academic research. The Industrial Research and Development Unit (IRD Unit) of IIT, Delhi, now guides the institute's policies regarding IPR issues; and elaborates the institute's policies regarding licensing of technology and ownership rights to technology generated in different modalities (this includes standard terms and conditions regarding contract research and consultancy, copyright issues, trademark issues, and control and evaluation of IP generated). Apart from this, professors of the institute have instituted a Foundation for Innovation and Technology Transfer (FITT), which also very actively participates in promoting the university–industry interface.

Government Initiatives

1. **Technology Development and Innovation Programme:** Earlier known as PATSER (Programme Aimed at Technological Self-Reliance), this programme is run by the Department of Science and Industrial Research (DSIR). It aims to promote industry's efforts in development and demonstration of indigenous technologies, development of capital goods, and absorption of imported technologies. To achieve self-sufficiency in industrial growth, it supports projects wherein national research organisations collaborate with industry.
2. **Technopreneur Promotion Programme (TePP):** This is a new initiative taken up jointly by the DSIR and DST in 1998–99. Its aim is to support individual innovators to become technology-based entrepreneurs.

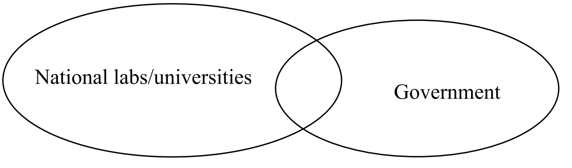
3. **Biotechnology Patent Facilitating Cell:** This has been established by the DBT. It aims to create awareness and understanding about intellectual property rights among scientists and researchers at all levels by arranging workshops, seminars, conferences, etc. It also seeks to provide patenting facilities to biotechnologists in the country, for filing Indian and foreign patents on a continuous basis.
4. **Home-grown Technology Programme:** Based on the suggestion by the Planning Commission, which is the apex arm of the Government of India for national planning, the Technology Information, Forecasting and Assessment Council (TIFAC) initiated this unique scheme of assisting the commercialisation of technologies successfully tried out in laboratories. This activity has provided a major impetus in promoting R&D efforts in various national laboratories and strengthening of linkages between research institutes and industry. TIFAC provides 50 per cent technical expertise and financial inputs, while the rest is provided by the user industry. It also provides infrastructural support.
5. **Technology Development Board:** This works under the statutory provisions of the DST to provide financial assistance to industrial concerns for the development and commercialisation of indigenous technology in a dynamic economic environment.

Discussion and Concluding Remarks

Even though the concept of the triple helix has a universal relevance, the level of its operation or practice varies in different socio-economic and national contexts, which in turn is determined by the structure of linkages between different actors. To a large extent it was found that the bilateral linkages between government and national laboratories and universities determine only the partial relevance of triple helix in the biotechnology sector in Delhi. Industry as one of the actors in the triad does not occupy a significant part (see Figure 2). Further from the evaluation of research links, it has been found that almost all public sector research institutes and universities had links with other institutes/universities either at national or international level, but there were hardly any formal partnerships with a company in the Delhi region, even though India presently can boast of a fairly mature pharmaceutical sector with many Indian companies (like Ranbaxy, Nicholas Piramal, Dr Reddy's, Cipla and Sun Pharma). So does this mean 'triple helix' is not relevant in the Indian biotechnology context?

Perhaps not. Many other countries show a similar trend, that is, absence of industry in triple helix lineages (at least in the initial stages of the biotechnology industry). Universities and national laboratories in the Delhi region, reflecting the general Indian situation, lack effective organisational and institutional mechanisms to foster and catalyse technology transfer and commercialisation of research results. In the Delhi region only the Indian Institute of Technology had institutionalised a technology transfer unit. Governmental schemes and organisational mechanisms to promote commercialisation of research lack financial and management capabilities, which have a 'space for risk-taking operations' in the absence of venture capital avenues.

FIGURE 2
Biotechnology Sector Linkage in the Delhi Region



Source: Sardana (2002).

These findings should not, however, be taken against the relevance of the triple helix model. There are studies that have shown that government funding in R&D dominates in the initial stages with bilateral relationships. Prevezer (2001) brings to attention that during the early stages of the development of the biotechnology industry in the USA (early 1980s), substantial funding came from the government. She recounts that in 1983 64 per cent of funding in biotechnology came from the federal government and another 8 per cent from state and local governments. Mansfield's (1995) study also shows that 61 per cent of funding for academic R&D in the pharmaceuticals field (in 1983) came from the federal government. Similarly, in other European countries funding from the government has been the norm. Prevezer (2001) has shown the extensive funding (for biotechnology R&D) by the government in the UK, and Giesecke (2000) reports the same for Germany. It then seems that extensive funding by the government towards the early stages of development of the biotechnology industry is a sort of norm. And the tripartite relationship in the biotechnology gets established a bit later, as has been the case in the US (where industry can be said to be in a mature stage). Bluementhal (1994) states that the National Institutes of Health, USA (NIH) share of biomedical research dropped nationally from 40 per cent in 1980 to 32 per cent in the 1990s, while industry share increased from 31 per cent to 46 per cent. Boyd and Bero (2000) also refer to a study that notes that in late 1990s, 28 per cent of surveyed life sciences faculty reported funding from private sponsors.

Given these observations, it is difficult to dismiss the triple helix model as yet for the biotechnology sector in India. As it is in the early stages, the bilateral relationship between academia and government seemed justified based on other countries examples. In fact, Turpin et al. (2002) and Pavitt (2001) also advise that governments, especially in developing countries, have to play a dominant role in the development of sectors that are of vital importance to the society.

The observations, however, also conform with the viewpoint of some researchers that S&T policies (in India) so far have largely concentrated on the 'input side' of R&D spectrum and left the 'diffusion end' to the natural play of different actors (Krishna 2001). This situation is especially of great concern as even the government insists on policies to forge greater tripartite relationships and the data reflect a high proportion of government funding for projects having some industrial relevance. Dr R.A. Mashelkar (director general of the CSIR) in his 'CSIR 2001: Vision and Strategy' (CSIR 2001) document also emphasises the need for strong public sector research–industry links so that most of the funding for research in public sector research is generated by industry.

The present study, which has the broad objective to explore the relevance of the triple helix in the Indian context with respect to the case of biotechnology in the Delhi region, has drawn attention to some S&T policy implications. An effort has been made here to suggest measures that an evolutionary bottom-up approach compared to the neo-corporatist top-down approach of triple helix is better suited to bringing about valuable networking for the innovation involving industry and academia.[24] The following measures suggested reflect the views of some leading research scientists in academia and national laboratories, and technocrats from the government:

1. Proactive steps should be taken by various concerned ministries to promote commercialisation of biotechnology and related sectors through venture capital. Various public financial institutions and banks could be drawn into forming consortia to fund potential

projects—given the high uncertainty in research in areas such as biotechnology. There are more than thirty-five software technology parks for the IT sector, but only few supported in the biotechnology sector in 2001. With more than a dozen research institutions and over six leading pharma companies in the region, there is a strong need to establish a biotechnology innovation park or incubation cluster in the Delhi region. In other words, the effort to establish regional innovation systems can bear positive fruits and can have long-term consequences for regional development and overall national development.

2. Despite the efforts by the government with a number of schemes, there is a feeling among researchers that these programmes operate in a limited scale and very little information is disseminated across institutions in the country. Dissemination of information for diffusion of technology by departments of science and technology is reported to be quite weak and ineffective. There is also a need to expand these programmes on a wider scale to involve universities and public sector research institutions with industry in a partnership mode rather than the present mode of 'government funding'. Closely related to the point of lack of venture capital, our estimate reveals that only a very small proportion of 15 to 20 per cent of cess money collected by the government from various industries and sectors for technology development and improvement is diverted to the Department of Science and Technology for its schemes.
3. National laboratories and universities, with the possible exception of units in the CSIR, lack organisational and institutional mechanisms to promote patenting and technology licensing offices or technology transfer offices. Steps should be taken to build human resource, with deep knowledge and understanding of the process of technology transfer, patent laws and other nitty-gritties of processes related to commercialisation of research. Steps should be taken to sensitise and educate faculty in universities and scientists about India's patent laws and various policies that are being framed in the biotechnology sector. It is also important that reward structures in national labs/universities give due importance to commercialisation of knowledge apart from publications.
4. It is observed that there is a need to frame policies that redefine not only the role of public research scientists, but also incentives related to it such that it encourages them to partner with industry

and be more open to patenting and commercialisation of research. There is a need to incorporate new norms and regulations in the university constitution to encourage triple helix based partnerships.[25] It is high time that the University Grants Commission and ministries related to science and education articulated an Indian version of the Bayh-Dole Act prevalent for US universities, with expanded provisions for incentives for researchers and for legitimising technology transfer offices in academia. For example, professors in universities in the USA and UK can create and own companies emerging out of their research with financial incentives to universities, and yet retain their faculty positions. In France CNRS scientists can have dual positions in their laboratories as well as universities. In India if scientists move from the CSIR to universities or vice versa, they have to tender their resignation and then take up a new position. The same applies to government and industry-related cases. This hinders mobility and scuttles dynamism in fostering partnerships between different actors in the national innovation system.

5. With the expanding private sector and globalisation of R&D in ICT- and biotechnology-related areas, the demand for professionals has increased considerably over the last few years. Our survey and interviews with leading researchers in the Delhi region revealed that universities and national laboratories, including IITs, are finding it difficult to attract the best talent given the 'greener' pastures across private sector laboratories and foreign companies. With the growing competition and demand for talent in modern biology, universities have to create conditions to attract the best talent and develop human resources in an effort to maintain excellence and research standards.
6. R&D capability of the industry is still generally weak and needs S&T policy mechanisms to boost its research capacity through certain effective tax incentive mechanisms. What is being suggested here are not more incentives, but legal support to monitor and evaluate R&D incentives already in place. For instance, science departments do not have either monitoring mechanisms or legal provisions to punish defaulters who obtain tax incentives for R&D and then involve themselves in unrelated activities.[26]
7. The triple helix framework, taken as an innovation strategy, is an important S&T policy component. However, universities across the

board cannot be pressurised too much to generate their budgets from external earnings through such policies. As argued elsewhere (Krishna 2001), only the top or the best of the existing universities (including IITs in the Indian case) may be in a position to respond to industrial challenges and yet maintain research excellence and standards of learning. From a long-term perspective, universities and higher research need to be viewed in the mode of 'science as public good'. There is a need to further examine the relevance of triple helix in the case of developing countries.

NOTES

1. 'S' here refers to science, 'T' to technology, and 'I' to innovation.
2. See Faulkner and Senker (1995: 206–11) for critique of pipeline model and a discussion on the chain-linked model and fifth-generation innovation process.
3. Triple helix I or an etatistic model of university–industry–government relations is a configuration wherein the nation-state encompasses academia and industry, and directs relations between them. A strong version of this model is found in the former Soviet Union and in East European countries under socialist governance. Weaker versions were formulated in many Latin American countries. It is now largely viewed as a failed developmental model, as innovation was discouraged rather than encouraged due to a strong bottom-up approach (Etzkowitz and Leydesdorff 2000).

   Triple helix II or the laissez-faire model consists of separate institutional spheres with strong borders dividing them, and highly circumscribed relations among the spheres. This is exemplified in Sweden and the USA. This model is advocated nowadays as shock therapy to reduce the role of the state in triple helix I (Ibid.).
4. The 'production puzzle' arises due to increasing need of technological innovation in the present context (that is, the 'new' economy). Etzkowitz (1998) finds the linear model to be a slow process of innovation and not too relevant in the present context. There is also the issue of balancing between long-term and short-term goals.
5. Science and technology is now increasingly being seen to resolve many social and economic problems in society. The crises for developed nations like the USA arise from increasing demands for funds for development of areas other than defence/military (like health and food security). There is also the realisation of equitable growth across all the regions within the country. Developing nations (like Eastern European countries, Africa, Latin America) have more problems to tackle. One of the major issues for them is to catch up with economic development so that society is able to realise the benefits of it.
6. A change in the funding system is supposed to be the key mechanism of change because reward structures influence performance parameters (Benner and Sandstrom 2000).
7. The process of capitalisation occurs in three stages: first, the securing of intellectual property; second, the restructuring of research groups to generate a large intellectual

property base; and third, the establishing of corporate vehicles, such as spin-off firms, within universities to maximise the return on intellectual property (Etzkowiz et al. 1998).

8. The definition of so called 'high-technology industries' vary, but generally are associated with issues like high R&D activity coupled with high uncertainty.
9. Ramani (2001) brings to notice that in 1976 the top twenty firms in India held 57.19 per cent of the pharmaceutical market; of these twenty firms, only four were Indian. Conversely, by 1995 only seven MNCs figured in the top twenty pharmaceutical companies in India, and they had only about 15.1 per cent of the Indian market.
10. Probably one of the reasons of lack of interest by researchers to work on such topics is lack of available data in India. For example, during the course of data collection I faced several difficulties. Apart from non-availability of data in one place, it was even difficult to get complete data. Many times it was even difficult to get previous annual reports.
11. The concerned people from whom the data is gathered are not included in the random sampling method; rather, it is purposive in nature.
12. Delhi was chosen as the region of study as it is supposed to have many government laboratories, universities of high repute, and autonomous academic institutes conducting research in various fields of biotechnology. At the same time institutes based in Delhi are actively engaging in technology transfers as compared to institutes in other regions, which makes it ideal for conducting study on budding relationships between university–industry–government in the biotechnology sector. DBT data showed that of total fourty-one technology transfers, twenty-one were from institutes based in Delhi. Of these twenty-one, seventeen were from public research institutes.
13. The CBT is a CSIR laboratory/R&D institute in the field of biotechnology and life sciences. It has now been renamed the Institute of Genomics and Integrative Biology (IGIB).
14. The NBPGR is affiliated to Indian Agriculture Research Institute (IARI), which has laboratories all over India.
15. The definition of biotechnology, appropriate to this research study, is 'the use of genetic engineering for practical purposes in living organisms (be it plants or animals) or some of their components (bacteria, mammalian cells)' (http://www.nccr-oncology.ch/en/glossary/glossary.htm).
16. After having gathered a list of ongoing projects in a particular institute, the researcher took help of other scientists in the area in order to differentiate between biotechnology and life sciences.
17. If the respective project leader/professor was not available temporarily, then it was decided to take data from a junior scientist or another scientist involved in that project. But if the project leader/professor had left the institute, then it was not considered and the exercise not undertaken.
18. The distribution of seventy-four projects in various institutes is: twenty-five in DU, eight in IIT, ten in CBT, four in AIIMS, eight in JNU, thirteen in NBPGR, and six in NII.
19. Mansfield's (1995) study showed that it is useful to take into consideration the 'total amount of funding' and 'total number of projects'. He observed that while four-fifths of the cited academic researchers got funding from industry, it actually supported substantially smaller percentage of the total research budget.

20. DRDO: Defence Research and Development Organisation; ICAR: Indian Council for Agricultural Research; UGC: University Grants Commission; and CPCB: Central Pollution and Control Board.
21. Data was not available for actual funding for six different projects.
22. Many scientists sometimes even marked their projects under two relevance categories, so it was decided to optimise the results in the best possible way (avoiding bias at the same time). If the project had two relevance categories, like academic as well as industrial, then the latter has been given importance as more emphasis is laid on the commercialisation aspect these days. However, if there were an even number of projects having relevance under two similar categories of funding source, then to reduce the bias and to optimise the result they were equally divided between the two heads.
23. 'Cultural expectations related to academic research behavior, as defined by the classic work of Robert Merton, are based on four key norms. First is [the] norm of *universalism* or the separation of scientific statements from the personal characteristics of the scientist. This norm ensures that the quality of academic work will be evaluated on the basis of the work itself, not the scientist's prestige or lack thereof. The second is *communality*, the sharing of research results and approaches with all other researchers. Communality ensures that research will be open to all challenges, subject to verification by replication, and widely disseminated. The third norm, *disinterestedness*, requires research to be detached from personal motives, pursued only for the sake of truth and intellectual progress. Finally, *organized skepticism* demands the critical and public examination of scientific work so necessary to ensure sound theoretical structures and correct deductions' (Louis and Anderson 1998).
24. Viale and Ghiglione (1998) reveal that the triple helix model can be interpreted in two ways:

    1. The neo-corporatist interpretation is focused on activities among the representatives of academia, industry and government, and is at the level of 'innovation coordinators'. The coordination committees have the role of planning the integration process, and there is no belief in the possibility of an endogenous evolution. This is more like a top-down model. This is not too satisfying in terms of integration of actors.
    2. In evolutionary interpretation the government's role is limited but very crucial. In fact it has to define the normative framework suitable for the planning of individual incentives for the reorientation of academic and industrial actors towards a higher integration.

25. According to Whitley (2003), the role of public sciences in supporting the growth of industries with a new generation of technologies has varied across nations due to different levels of reputation-related competition, and intellectual pluralism and flexibility. These in turn are affected by the extent of delegation of the resource to the scientific elite, concentration of administrative and intellectual control within institutions, the stability and strength of the hierarchy of research organisations, and organisational segmentation of research goals and labour markets. It is imperative that while formulating policies these are taken into account and measures suitable to the Indian context formulated.
26. Presently, the DST provides certain tax incentives to companies for the money spent on R&D, but unlike South Korea, there is no legal or penal support to punish companies

that obtain R&D tax incentives but by and large perform only ordinary routine activities, like quality control testing. There is a need for a good legally supported monitoring system to be put in place for dealing with R&D tax incentives.

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