Science, Agriculture and Public Policy: A Study of Government-Academia-Industry Networking in India

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Introduction

Agriculture research in India faced a major paradigm shift in the 1990s in response to issues emanating from the Convention on Biological Diversity (CBD) and Agreement under the World Trade Organisation (WTO). The provisions of the Trade Related Aspects of Intellectual Property Rights (TRIPS) Agreement of the WTO established enforceable universal minimum standards of protection for all major forms of Intellectual Property Rights (IPR), of individual or institute, for new knowledge skills, technologies and products developed by them. Also, it extended the application of the IPR regime to living things and agricultural research. This leads to the commercialization of Indian agriculture. The changing nature of research in agricultural biotechnology in developing countries like India requires expertise from diverse fields that has made collaboration among researchers from diverse fields essential. In a developing economy like India, university-industry networking has remained low. In the 1960s, the High Yielding Varieties (HYV) of seeds were adopted to increase the volume and rate of agricultural production. The HYV seed was owned by the State and there was no ownership of the private sector over the seed. However, as the agricultural sector entered in the era of genetic modification, there was a transition in the ownership of state to the multinational corporations (MNCs) over the production and use of the seed. Investments in such genotypic research cannot be fulfilled by the public sector alone and this calls for broader participation from private R&D. Owing to the corporatization of invention in agricultural biotechnology, the private sector is now playing a key role. In order to utilize the full benefit of research and innovations, it is important to understand the public-private networking aiming at concrete deliverables.

A new form of knowledge is created through the intersection of the interests of academia, industry and government. In this context, the thesis critically examines the networking between agricultural biotechnologists in various institutional settings, viz. government, academia and industry. The networking between academia and industry was legalized through the introduction of Bayh-Dole Act in 1980. Further, the concept of IPR was introduced to the research outcome coming out of public funded research institutes. This act was a historical step in institutionalizing/legalizing research outcomes of public research institutions/universities. It is in this context, thesis critically examine the networking between various scientists of agricultural biotechnology in institutional settings of government-academia-industry. The major hindrances to collaboration between scientists engaged various institutional settings in India is identified as lack of mutual trust, lack of understanding between potential collaborators, difficulties in finding potential collaborator bureaucratic administrative process, inability to send samples abroad, lack of funding and so on.

Review of Literature

Historical Background to Agriculture Research in India

There is a need of the new vision for agricultural technology development that can deal with complexities across the diverse settings in India. Agriculture in developing countries including India not only involves semi-skilled and unskilled workforce but also low on technological intervention. Hence, any technology that would result in the decrease in cost or improve the crop yield will be highly valuable.

Involvement of private sector is particularly being important especially with the involvement of the biotechnology sector and patent being granted under IPR. New biotechnology research is expensive and cannot be supported by the government institutions alone. So, there is a need for private sector involvement for the contribution of funding in the areas of agriculture research and extensive activities. Biotechnology is seen as an emerging industry in the countries like India. The relationship between private sector and the state is important to understand the politics of biotechnology policy processes in developing countries like India. The state often plays a crucial role by way of appropriate policy intervention to promote particular sector (Parthasarthy and Joseph 2002). In addition to the Indian Council of Agricultural Research (ICAR) and state agricultural universities, other state and central universities are engaged in agricultural research. However, in the wake of economic reforms in the 1990s and slash in public funding in the agriculture sector, the private institutions started playing an important role by investing increasingly in agricultural field especially in the area of biotechnology. The agricultural sector has undergone a transition from pre-liberalization era to post-liberalization reform. These transitions require input from various fields ranging from expertise, funding, networking to diffusion and commercialization of technology by involving varied actors. Owing to India’s post colonial developing country orientation, policymaking and policy research have been framed through the terms of development and planning (Mathur 2013). The future of Indian agriculture is bound to be affected by the number of emerging scenario like shrinking land availability, lack of land reforms, absence of minimum support price, etc, but most importantly corporatization of agriculture research may have a bearing on future agriculture.

Sociology of Science and Technology

Sociology of science and technology (S&T) may be examined as a part of sociology that studies relationships between different idea systems and a variety of institutional and personality factors. It is a relatively new field in the sphere of science studies and technology, which has traditionally been dominated by philosophy and history of science. It deals with the social relativism of scientific research and its knowledge products. It informs that scientific research is a process, which involves social interests and the major social forces that prevail upon the working of a scientist. The S&T is a specialty that examines the circumstances under which science is practiced and technology I developed (Calhoun 2005). The sociology of science dates back to the late 1930s, where Robert K. Merton (1970 (1938) displaced the then existing Marxist perspective with a generally sociological approach to knowledge. In what come to be called the institutional approach to science, some of the important questions concerned the social organization of science and the 'institutional imperatives' or norms and values, that sustained the scientific attitude from within (the norms were universalism, disinterestedness, organized skepticism and communism). The generation which followed turned its back on the functionalist mode of reasoning which is evident in these concerns and which Merton, like Parsons had adopted. It collectively moved away from the focus on social-structural and institutional processes characterizing scientific groups and organization, arguing that science cannot be understood if the cognitive content of science and technology, and the processes of knowledge and technology creation are not included in the analysis. This attitude was encouraged by the work of Kuhn (1970 (1962) and Feyerabend (1975) who espoused a philosophy and historiography of science in which they traced the independence of cognitive and social factors in the history of physics and other disciplines. The outcome of the collective change of mind was that the sociology of science and technology turned into a sociology of knowledge also called 'the new sociology of science' and science and technology studies.

Contours of Public Policy

Public policy is influenced by and influences several other fields of study and is highly interdisciplinary in nature. It is important to note that public policy is not just a government action, since non-action at times has deliberate consequences. As Jones (1984) states: "a goal directed or purposive course of action followed by an actor or a set of actors in an attempt to deal with a public problem".

A policy process is fluid and varied; it changes over time and from policy to policy. Charles Jones (1984) describes five stages through which public policies usually pass. Let us discuss these in detail. First, citizens, interest groups, or policy makers must perceive and define a problem and thereby bring it to the public agenda. Second, policy makers formulate and debate possible solutions in Congress or the executive branch. Third, they adopt a set of solutions as law, an executive decision, or a regulation. In the fourth stage, bureaucrats study the programme and allocate resources to implement the policy. This task is often complicated by political pressures to delay or alter a programme. In the fifth stage, policy makers evaluate the outcome of the first four stages, but an assessment can be performed during any phase of the process and by any person, group, or institution. Finally, all the above mentioned stages rarely follow a proper chronological sequence, rather than subject to political maneuvering and bargaining. Thus, public policy has to be understood within the nature of an uneven structure of the society.

Models of Policy Process

Let us discuss general models which have provided useful perspectives on policy process. One is the rational model, which assumes that policy makers have clear goals, the ability to assess many alternative courses of action, and the willingness to choose those policies that achieve their goals at the least cost. This model emphasizes neutrality, objectivity, thoroughness, consistency, and the use of quantitative measures whenever possible, so it bears a close resemblance to the ideal scientific method. Other models emphasize the limitations of policy makers, Barke (1985) argues that policy makers take current policies as a starting point and make only incremental changes, thereby avoiding the need for clear definitions and searching analyses. In this model, policy makers lack time, ability, and resources to be thorough; instead, they try to adjust the old policies. The incremental policy model might be familiar to practicing scientists because it blends the spirit of the perfect scientific method with the real obstacles of being thorough. The incremental policy model lacks the capacity to accommodate unexpected changes which may alter the policy objectives. The third model is the garbage can model in which government is described as an "organized anarchy". Personal preferences are unclear, learning is by trial and error (therefore incomplete and not easily shared), and policy participants change easily due to personnel turnover or the reassignment of tasks (Barke 1985). Policy choices are similar to a "garbage can into which various kinds of problems and solutions are dumped by participants as they are generated". Most importantly, policy outcomes depend on the coincidence of three major process steams: problem recognition, policy formation and politics. The garbage can model describes a messy policy process that is difficult to predict. Just as the sciences occasionally undergo unexpected changes ("paradigm shifts" or "scientific revolutions") due to inadequacies of earlier theories, delayed and limited responses to poorly understood problems characterize the policy process (Kuhn 1970).

Moreover, the formation of public policy is an inherently political activity that requires both accumulation of facts and the weighing of personal values. But most importantly, the fundamental task in policymaking is to move from what is to what someone believes should be. Yet public policies are formed from an aggregation of individual desires that may not be based on present reality. In general, policy process is pervaded by the tensions between scientific procedures to gather and analyse knowledge and the amorphous quid-pro-quo political bargaining. Tensions also characterize science and technology policy: tensions between simplicity and reality, scientific understanding and social utility, public participation and professional competence, and short political time horizons and long scientific perspectives (Brooks 1982).

Thus, if the process of policymaking depends solely on political forces, the techniques and results of scientific inquiry would be ignored because objectivity will be irrelevant in this case or subverted to disguised subjectivity. In contrast, if policymaking depends solely on rationality and logic, scientific knowledge would be embraced and encouraged. But in practice, public policies usually fall somewhere between these extremes combining political necessities with scientific knowledge. Often 'objective' parts of the policymaking are nearly contaminated by the subjective values of interest groups, public opinion, or even the decision makers themselves. While comparing the costs and benefits of policies, conflicts between scientific facts and political values become crucial.

Post-academic Science

Since the 1990s, there has been a transition from academic science to post-academic science (Ziman 2000), from being a curiosity-driven research to contract obligations. In other words, we witness a transition in the production of scientific knowledge from being a public resource to an intellectual property. According to Merton (1968), academic science, as discrete institutional order, differs from industry on the basis of academic values, norms and conventions. In this context, agriculture in India is often said to have remained largely outside the disciplines governing international trade. But this view is partial in the legal sense, as the General Agreement on Tariffs and Trade (GATT) has been applied in full to agriculture. The original GATT 1947 has applied to trade in agriculture also, but it allowed various exceptions to the rules on non-tariff measures and subsidies, which led to several distortions in world agricultural trade. For example, the GATT in 1947 allowed countries to use export subsidies on agricultural products whereas export subsidies on industrial products were prohibited. The GATT rules also allowed countries to resort to import restrictions (e.g. import quotas) in the agricultural sector under certain conditions, notably when these restrictions were necessary to enforce measures to effectively limit domestic production. The result of all this was a proliferation of impediments to world agricultural trade. Including by means of import bans, quotas setting the maximum level of imports, minimum import prices, non-tariff measures maintained by state-trading enterprises, etc. The need of liberalization in the world trade in agriculture was felt due to extensive subsidization by the developed countries which led to the distortion in the prices of agricultural commodities. Till 1995, export subsidies came to dominate many areas of world agricultural trade, while the disciplines on import restrictions were often flouted. The 1986-1994 Uruguay Rounds went a long way towards changing all that. Agricultural trade is now firmly within the WTO multilateral trading system. The agricultural agreement, together with individual countries' commitments to reduce export subsidies, domestic support and import barriers on agricultural products were a significant first step towards reforming agricultural trade. Whether developing countries will be able to protect their plant genetic resources and the rights of local communities to control and enjoy the benefits of their traditional knowledge will be determined both by policies adopted by the World Trade Organization (WTO) and by the domestic policies these nations implement within their respective countries' (Plahe and Nyland 2003).

Triple Helix Model of Innovation

The concept of the triple helix of university-government-industry relationships initiated in the 1990s by Etzkowitz and Leydesdorff (1995) which elucidates the shift from a dominating industry-government *dyad* in the industrial society to a growing triadic relationship between academia, industry and government in knowledge society. An evolutionary view of triple helix dwells upon the institutional perspective of private and public control at the level of academia, industry and government which enables various degrees of selective mutual reconciliation (Leydesdorff and Etzkowitz 1998). In triple helix system, networking in formal and informal structures at regional, national and international levels is one of the major forms of interaction. The networking between government, academia and industry is necessary for the knowledge production in agricultural biotechnology processes. According to (Etzkowitz 2013), it is where most creative synergies emerge and set in motion a process of innovation in innovation, create new venues for networking and organizational formats as an individual and organizational actor not only perform their own role but also exchanges the role of the other.

From the perspective of neo-evolutionary perspective, inspired by the theory of social system of communication and mathematical theory of communication, which suggests, academia, industry and government are co-evolving sub-sets of social systems that interact through an overlay of recursive network and organization that reshape their institutional arrangement through reflexive sub-dynamics such as markets and technological innovation (Leydesdroff 2008). Triple helix is significant in understanding the networking between different actors in agriculture innovation system which roughly relies on the traditional mode of knowledge diffusion

Research Gap

Triple helix model in the case of biotechnology is not fairly explored in the context of developing countries such as India. The present study is an attempt to understand the networking between government-academia-industry in formal and informal structures by directly investigating the motivation, interest and organizational mandates of different institutional settings. What are the challenges 'scientists' accrue in the course of forming such networking or collaboration is studied previously with very little focus? Triple helix model/government-academia-industry interaction is complex and its qualitative analysis is difficult in the case of developing countries like India. It extrapolates the functions, interaction and problem within triple helix. There is a little information on informal collaboration between various sectors. Hence, a detailed study regarding informal collaboration between varied actors, viz. government, academia and industry is carried out to better capture the emergence of such knowledge society.

The Science, Technology and Innovation Policy (2013) of the Government of India promotes the public-private partnership (PPP) in the case of agricultural biotechnology in India but how PPP model works in National Innovation System (NIS) is not fairly explored. What are the government policies/Challenges that are transforming the traditional NIS in India together with institutional mandates outlined to promote NIS system in India?

Moreover, when we consider the case of GM debate, it is mostly targeted between GM and non-GM debate. It will be interesting to examine how biotechnology is shaped by the conflicts of interest among varied stakeholders. It studies the implications of proprietary technologies in agriculture in India where two genetically modified crops, namely Bt Cotton (non-food crop) and Bt Brinjal (food crop) have been analyzed critically. It discusses debates and politics about biotechnology in general and Bt crops in particular. It critically examines how diverse actors involved in the process have their own interests and meanings. It also tries to study the networking between the government, academia and industry with a special focus on Bt Cotton and Bt Brinjal. It further argues how increased networking and interaction between these three actors namely, government, academia and industry will have better adoption of agricultural biotechnology as well as it will lead to policy level changes required for GM crops.

Rationale for the Topic

The present study attempts to examine the networking between government, academia and industry in agricultural biotechnology in India. With the advancement of research, complexities of research have increased which require more collaboration among diverse disciplines and geographical locations. In India, public investment continues to fund the major portion of R&D activities and there is chronic dearth of funding in agricultural research for a long time. This calls for enhancement of partnership especially from private sector's investment in agricultural R&D and non-R&D activities. The government is trying to promote PPP model in agricultural biotechnology by funding projects involving actors from government, academia and industry, incubation facilities, startups and so on. In India, there is a constant effort to reach tri-lateral or triple helix model of innovation in agricultural biotechnology through networking and partnership. It also tries to study the status of GM crops in India against the backdrop of challenges posed by the different sections of the society. The challenge is to understand dynamics and debates and develop ways to deal with these challenges. The introduction of technologies is frequently marketed by governments, donor agencies and private businesses as 'safe and good' – even where the intrinsic contribution of such technological innovation to human safety remains under the scanner. In this context, it is significant to understand how India should position itself in relation to Bt seeds to suit the need of poor farmers.

Research Questions

The present study centres on the following research questions:

(a) To what extent and in what ways the networking between the government, academia and industry promotes or otherwise proprietary technologies in agriculture? In other words, it is important to examine the interests and meanings associated with proprietary technologies in agriculture as well as various actors and institutions in India. It will be interesting to note how these debate and contested views on Bt crops can lead to policy suggestions which are critical for the appropriate utilization of new technologies in Indian agriculture.

(b) What are the institutional mandates and policies outlined to enhance knowledge production in agricultural innovation system in India? Further, it tries to examine the factors which lead to innovation/knowledge production in agricultural innovation system in India.

(c) What are the factors which lead to the hindrances to collaboration? What motivates the scientist to collaborate with industry or otherwise? It tries to examine networking between government, academia and Industry by enquiring or capturing the views/understanding of scientists on research collaboration. Putting it succinctly, it tries to examine the status of triple helix model of innovation in agricultural biotechnology in India through patents, publications, projects, intellectual antecedents, informal networking ties, and so on.

Objectives of the Study

The objectives of the proposed study are to:

(a) Understand the implications of the implementation of proprietary technologies in agriculture in India;

(b) Examine the institutional mandates outlined to promote innovations in agricultural biotechnology research in India;

(c) Examine the processes of government-academia-industry networking towards knowledge production in agricultural biotechnology in India.

Methodology

The present study, from the sociology of science and technology perspective, attempts to understand the perspective of plant scientists on the current state of Bt seeds in agriculture in India, together with potential or actual applications, in order to address the social, economic, political, cultural, ethical, legal, institutional and ideological issues. It also tries to understand the networking between government, academia and industry on agricultural biotechnology in India and how this networking leads to the innovation/knowledge production in the agricultural biotechnology sector. Science and technology are only half the way to public acceptance. The study was carried out through both primary and secondary data. The primary data include in-depth personal interviews with scientists engaged in research in plant biotechnology in the government, academic and private R&D institutions in India. Interview guide and questionnaire helped us ascertain the views of various stakeholders about Bt seeds in agriculture in India. Content analysis was be deployed to analyze the interview material. Coding was done on the basis of themes and off-repeated statements.

The multidimensional approach has been adopted by looking into various aspect of research like (affiliation, researchers' background, references, citation, and instrumentalities). Triangulating information from interviews, publications, patents and other complementary sources (i.e. CVs, personal and laboratory homepages) have been analyzed.

In-depth personal interviews with scientists of different institutional settings like government, industry and academia have been carried out. Scientists from government departments such as Indian Agriculture Research Institute, New Delhi; scientists from academic institutions such as University of Hyderabad, University of Delhi, Jawaharlal Nehru University; and scientists from industry such as Monsanto and Criyagen are interviewed. Scientists interviewed for the present study are specialized in the areas like genomics, genetics and engineering, Biotechnology, Proteomic, seed science and technology, entomology, plant molecular biology, Plant virology, biophysics, Marker assisted Selection Breeding, plant pathology, transfer of technology and product development. The study was conducted in public institutions such as universities (central, state and deemed universities), ICAR-sponsored research institutions, mission-oriented research institution supported by the government, Institutes of National Importance, CSIR laboratories, international research institutions, the private research foundation and so on.

Among the means used for data collection was a questionnaire to elicit information related to employment, experience both teaching and research, institutional affiliation, research output such as publication and patent. Also, in-depth personal interviews with individual scientists were conducted in their laboratories and interestingly purely qualitative responses given in the interviews provided rich insights into the perceptions, attitudes, and the dynamics of interaction.

Table I: Scientists' Affiliation

I	International			
	A	Public		4
	B	Private		1
II	National			
	A	Public		
		a	Universities	
			(i) Central Universities	7
			(ii) Deemed Universities	1
			(iii) State universities	11
		b	Institute of national importance	3
		c	Mission-oriented Research Institutes	
			(i) CSIR-sponsored Research Institutes	18
			(ii) ICAR-sponsored Research Institutes	31
	B	Private		
		a	Private Foundation	3
		b	Industry	2
***Total number of scientists interviewed*:**				81

Table II: Total Number of Institutes and Respondents

Sl. No.	Institutes	Respondents
1	International Centre for Genetic Engineering and Biotechnology (ICGEB), New Delhi	2
2	International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad	2
3	University of Delhi (UoD), Delhi	2
4	Jawaharlal Nehru University (JNU), New Delhi	3
5	University of Hyderabad (UoH), Hyderabad	2
6	Indian Institute of Science (IISc), Bangalore	1
7	Guru Gobind Singh Indraprastha University (GGSIPU), Delhi	2
8	University of Madras (UoM), Chennai	3
9	Osmania University (OU), Hyderabad	1
10	Anna University (AU), Chennai	1
11	Calcutta University (CU), Kolkata	3
12	University of Pune (UoP), Pune	1
13	Indian Institute of Technology Madras (IITM), Chennai	3
14	National Centre for Plant Genome Research (NCPGR), New Delhi	1
15	Bose Institute (BI), Kolkata	7
16	National Chemical Laboratory (NCL), Pune	4
17	Centre for Cellular and Molecular Biology (CCMB), Hyderabad	1
18	Indian Institute of Chemical Biology (IICB), Kolkata	2
19	Indian Agricultural Research Institute(IARI), New Delhi	4
20	Agharkar Research Institute (ARI), Pune	6
21	University of Agricultural Sciences (UAS), Bangalore	14
22	Indian Institute of Rice Research (IIRR), Hyderabad	4
23	Saha Institute of Nuclear Physics (SINP), Kolkata	2
24	National Centre for Biological Sciences, Bangalore	3
25	Indian Association for the Cultivation of Science (IACS), Kolkata	1
26	M.S.Swaminathan Research Foundation (MSSRF), Chennai	3
27	Criyagen, Bangalore	2
28	Monsanto India Ltd.	1
	Total Number of Institutions: 28	**81**

Content analysis is a general term for a number of different strategies used to analyze text (Powers and Knapp 2006). It is a systematic coding and categorizing approaches used for exploring large amount of textual information unobtrusively to determine trends and patterns of words used, their frequencies, their relationships and the structures and discourses of communication (Mayring 2000; Pope et al 2006 and Gbrich 2007). Qualitative Data Analysis (QDA) software has been used to analyze interview transcripts. QDA Miner helped in coding, annotating and retrieving and analyzing large number of interview transcripts. MS Excel and Minitab have been used to analyze questionnaire. The analysis focuses on Indian agricultural biotechnology research system. Performance levels of scientific collaboration between public-public have characterized under three categories: Low: 0-50%, Moderate: 51-75% and High: Above 75%. First we have to calculate mean and standard deviation (sd) for all the observant. After this these performance level have been characterized under low, medium and high category. The formulas for calculating low, medium and high performance level are as follows:

Low: < (mean-1/2sd)

Medium: mean-1/2 sd to mean + ½ sd

High: > (mean+ ½ sd)

The secondary sources of data collection include books, journals, government reports and policies. The interview of the scientists was conducted from September 2014 to April 2015. Scientists interviewed for the present study belongs to the field of Genomic, Plant Molecular Biology, Genetic Engineering, Entomology, seed science and Technology, Plant Virology and Plant Pathology, IPR policy expert, Marker Assisted Selection breeding and so on.

Profile of the Respondents

Let us look at the profile of scientists interviewed for the present study. A majority of scientists interviewed are above the age of 50 out of which 66.7 per cent are senior scientists indicating that they are witness to pre- and post-WTO-regulated IPR regime. A scientist who is above the age of 50 and has research experience for more than 15 years is classified as the senior scientist. Senior scientists have more social capital, more publications, more research grants, and also work more prolifically with industrial collaborators. Also, 39.5 per cent of scientists interviewed completed their doctoral research in India, 6.2 per cent of scientists completed their doctoral research abroad. On the other hand, 11.1 per cent completed their doctoral and post-doctoral research in India, 43.2 per cent completed their doctoral studies in India and post-doctoral studies abroad. 49.4 per cent of scientists interviewed had international exposure at varying period of their research studies.

Table I: Classification of Scientists by Age

Age Group (years)	**Scientists (N=81)**
	Number
30-40	9 (11.1)
40-50	28(34.6)
50-above	44(54.3)
Total	**81(100)**

Note: Figures in parentheses indicate percentage to column total

Table II: Classification of Scientists by Designation

Designation	**Scientists (N=81)**
	Number
Scientist	27(33.3)
Senior Scientist	54(66.7)
Total	**81(100)**

Note: Figures in parentheses indicate percentage to column total

Table III: Classification of Scientists by Research Experience

Research Experience	Scientists(N=81)
	Number
No	16(19.7)
5-15 years	28(34.6)
15-25 years	20(24.7)
25-35 years	17(21.0)
Total	**81(100)**

Note: Figures in parentheses indicate percentage to column total

Table IV: Classification of Scientists by Intellectual Antecedents

Intellectual Antecedents	Scientists (N=81)
	Number
PhD (India), PDF (Abroad)	35(43.2)
PhD (India), PDF (India)	9(11.1)
PhD (India)	32(39.5)
PhD (Abroad)	5(6.2)
Total	**81(100)**

Note: Figures in parentheses indicate percentage to column total

1.8 Chapter Scheme of the Thesis

CHAPTER I: INTRODUCTION

The **first chapter** introduces various facets of the thesis: reviewing of literature in the areas of sociology of science and technology, historical background of agriculture research in India, networking and collaboration, on networking expertise, public policy and its stages, models of the policy process, WTO, globalization and Indian agriculture, understanding IPR and agriculture, triple helix model of innovation, and so forth, and then moves on to identify research gap, rationale, formulate research questions, set objectives and methodology, and chapter scheme of the thesis.

Chapter II

Transition in agriculture research system in India: a historical-sociological survey

Chapter III: Government-Academia-Industry: Examining Triple Helix Model of Innovation in Agricultural Biotechnology

Chapter IV: Triple Helix Model of Innovation and the Politics of Genetically Modified Crops: Cases study of Bt Cotton and Bt Brinjal in India

Chapter V: Debating the Controversies: A Study of Agricultural Innovation System in India

Chapter VI: Conclusion

Chapter II

The **second chapter** discusses Mode I and Mode II forms of knowledge production, triple helix model of innovation, biotechnology innovation, agricultural innovation system, directed basic research, science and technology policies in India, agricultural policies in India, public-private partnerships, networking between government, academia and industry, international politics of genetically modified food, situating biotechnology debates in the context of triple helix model of innovation, biosafety, science of GMOs, risks associated with new technologies, cases of Bt cotton and Bt brinjal, technology input in agriculture, low-external-input technology (LEIT), organic farming, and so forth.

CHAPTER III

Government-Academia-Industry: Examining Triple Helix Model of Innovation in Agricultural Biotechnology in India

Chapter III examines the processes of government, academia and industry networking and how this networking results into knowledge production in agricultural biotechnology in India. For this purpose a detailed study of the profile of scientists working in various research institutions, industry and universities have been studied and interviewed. The profile of the respondents has been discussed in the section on ‘methodology in chapter I.

Further, it illustrates the basis of their collaboration, starting with 'what is scientific collaboration?' This chapter also tries to answer the factors which lead to the hindrances to collaboration or hamper/discourage the process of collaboration between varied actors. In the process, it also tries to capture how this networking leads to knowledge production/innovation in agriculture through patent filed by scientists, projects, and publications made by scientists in peer-reviewed journals and other informal collaboration for expensive equipment facilities, informal communication and so on.

Genealogy of Collaborative Networking in Agricultural Biotechnology in India

The changing nature of research in agricultural biotechnology in developing countries like India requires complementarities of expertise from diverse fields. In a developing economy like India, university-industry networking has remained low. The high yielding varieties of green revolution were owned by the public sector as the state was the sole sponsor of scientific research till the 1980s. It is necessary to develop networking with the private sector so that the benefit of modern technology can be harnessed for the public use. The significance of the private sector has to be understood in the context of changing priorities in scientific research. In other words, the entry of private sector in Indian agricultural biotechnology has paved the way for different modes of institutionalization of agriculture in India. Indian government plays a vital role in the promotion of biotech sector in the country by setting up of institutions, offering technical and financial assistance to the individual and research institutions. This calls for increased participation from government, academia and industry for the production of knowledge. These new forms of networking between varied actors are significant for the creation of knowledge society. The networking between government, academia and industry is necessary for the knowledge production in agricultural biotechnology processes. Triple helix is seen as key to innovation and socio economic development of knowledge societies. Earlier Indian agriculture was predominantly owned by the public sector but with the advent of IPR the role of private sector in Indian agriculture has started growing slowly. There has been a transition from government-academia relations to government-academia-industry relations since the 1990s in India. According to sociologist Knorr-Cetina (1999), the field of molecular biology was individual centric and non-collaborative science as compared to other fields like physics during the 1980s. But with the advancement of science and increase in the complexity of research, several studies in the 1990s began supporting the evidence of collaboration in biology.

Interaction among the actors within a network is an important element for the efficient working of a system of innovation (SI). Innovation performance of a country depends on the interaction and networking between varied stakeholders (Dahlman and Utz 2005). The potential of economic development and innovation in knowledge society lies in the most prominent role in the hybridization of various institutions like government-industry and university and forming the network which generates in new knowledge (Ranga and Etzkowitz 2013). The networking between two public or private domains may be easier or difficult to determine and will depend on the period of networking ties, visibility, membership or activities in the public domain.

The main objective of scientific collaboration is to strengthen the scientific and technological capabilities of India's R&D institution in biotechnology and to establish a network for product development and technology transfer. 'Phenotype' of the triple helix partners (government, academia, and industry) can be expected to carry genotypical functions such as knowledge production (in science), income generation (in the market), and governance at different levels (Ivanova and Leydesdorff 2012; Hodgson and Knudsen 2011). Mutual information in three (or more) dimensions can be positive or negative and thus indicate cooperation or a lack thereof in triple helix networking. Triple helix is one of the most important insights of innovation because the most favourable innovation takes place at the intersection of government, academia and industry.

Networking in agricultural biotechnology in India mainly operates for the purpose of getting costly laboratory facility, to commercialize laboratory products and to get interdisciplinary expertise like variety or germplasm (IPR-enabled or otherwise), other products (e.g. vaccines, bio pesticides, equipment, software, technologies, processes, methodologies, information know-how, publication, services and so on.

Collaborative Networking in the Present Study

Collaboration in agricultural biotechnology requires expertise from diverse fields. The R&D organizations need research capabilities for the adaptation of technologies to local condition and the development of products addressing local priorities. This requires strategic public-private partnership. Networking is important to bridge the gap between result created by projects or laboratories and industry' ability to use them. Technology transfer from university laboratories to firms is considered key to strengthening competitiveness. Commercialization of research was supported by the introduction of Bayh-Dole Act in 1980 which allowed universities to patent and exclusively licensed discoveries generated as a result of collaboration between private sectors or otherwise. Further, "Stevenson-Wydler Technology Innovation Act of 1980" paved the way for increased cooperation between academia, federal laboratories, labour and industry through technology transfer, joint research, personal exchange and others see (Lee 1996). When we look at collaboration, it occurs at different levels such as between individual scientist of the same department, between research groups of one department to research groups of another department of the same institutions, between institutions, between different actors (government, academia and industry) and also at national and international levels. Sometimes these collaborations are overlapping and intertwined. Depending upon the individual's experience the definition of scientific collaboration varies from scientist of one institution to a scientist working in another institutional setup. A senior scientist from Indian Agriculture Research Institute (IARI), New Delhi states:

> *Scientific collaboration can be cooperation between two industry, organization or governments in terms of ideas, methodologies, equipment, expertise, training, data interpretation, analyse, and publications. All steps are to be involved in converting idea to product. This will lead into collaboration.*

Scientists interviewed for the present study are engaged in projects with Department of Science and Technology (DST), Department of Biotechnology (DBT), Council of scientific and Industrial Research (CSIR), Indian Council of Agricultural Research (ICAR) and private industry like seed companies etc., other state and central universities for projects with a less number of scientists working with industry or in collaboration with international organizations.

Research objectives of the scientists vary depending upon the nature of institutes they are affiliated with, and their networking partners they are engaged with for a specific project. Obviously, individual's interest guides the research problem undertaken by the scientist but it also depends on the rules and regulations of the research grant, and policies of government bodies.

The hindrances to collaboration have surfaced through lack of understanding, lack of trust and cooperation, personality clashes, unequal distribution of workload based on expertise, structural, institutional and organizational frameworks, bureaucratic administrative processes, lack of networking skills abroad and debilitating effects of funding. In order to establish an effective collaboration between the three actors, following points should be implemented at policy levels. Let us discuss these points in detail:

Networking is essential and complex phenomena in agricultural biotechnology. Networking ties help facilitate learning and production of new knowledge in the complex networking ties. Terms and conditions should be agreeable to both the industry and university. Secondly, coordination between industries and the public institution is lacking. Thirdly, the government has got the managing role. Project Research Officer of funding agency can monitor them. If there is any misunderstanding between university and industry than it can be sorted out. The smooth release of the fund should be promoted. The role of government is to create institutional framework which will enable actors to carry out different roles both locally and globally.

Table V: Association between scientific collaboration of public-private and performance level

No.	**Public-private**	**Percentage %**	**Sample (n)**	**Performance Level**				**X^2 Test**
				Moderate		**High**		
				N	%	N	%	
I	Government-Industry	6.1	6	4	66.7	2	33.3	**0.41** NS **(p=0.939)**
II	Academic -Industry	44.3	43	27	62.8	16	37.2	
III	Government - Academic Industry							
a	National	31.0	30	19	63.3	11	36.7	
b	International	18.6	18	10	55.6	8	44.4	

NS: Non-significant, **X^2 (0.05,3df) = 7.815**

Let us examine the collaboration between public and private organizations. This can be studied by examining the networking between government and industry, academia and industry, and government, academia and industry at both national and international levels. Around 6.1 per cent of the scientists are engaged in collaborative networking with government and industry. A total of 44.3 per cent of the scientists are engaged in collaborative networking with academia and industry. As scientists from universities collaborate with industry for the purpose of commercialization of their research results, transfer of technology, field test, etc. triple helix model can be located within networking between government, academia and industry and this type of networking is useful while considering the complexities and requirement of present day research in agricultural biotechnology. Looking at government, academia and industry networking within India, 31 per cent of the scientists are working in collaboration with government, academia and industry. A total of 18.6 per cent of the scientists are engaged in collaborative networking between government, academia and industry at international level.

Let us discuss association between scientific collaboration of public-private type and its performance level. When we look at collaboration between government and industry and its performance level, 33.3 per cent have high performance level. However, 37.2 per cent have high performance when we analyse the collaborative networking between academic and industry. Further, when we consider the collaborative networking between government, academia and industry at international and national levels, the performance levels are 36.7 and 44.4 per cent respectively. The Chi-square test for the present study is non-significant.

These figures suggest that academia-industry, university-national research laboratories, national research laboratories-industry collaboration is more dominant in agricultural research in India. Though some initiatives by the Department of Biotechnology of the government of India have been undertaken to bring in public and private research organizations on particular projects but growth of such type of partnership is limited to few research institutions and universities. For example, C-CAMP, Bengaluru under the Biotechnology Ignition Grant (BIG) initiative is trying to bring about private R&D and startups in close interaction with the universities where initial development grant is provided by the government and equipment facilities, mentoring facilities and infrastructure facilities are provided by the C-CAMP.

Chapter IV

Triple Helix Model of Innovation and the Politics of Genetically Modified Crops: Cases of Bt Cotton and Bt Brinjal in India

The fourth chapter attempts to understand the implications of proprietary technologies in agriculture in India where two genetically modified crops namely Bt cotton (non-food crop) and Bt brinjal (food crop) are analyzed critically. Further, an attempt is made to unfurl the debates on the policies of biotechnology, in general and Bt crops, in particular. This chapter examines how diverse actors are guided by differing interests and meanings. It attempts to study the networking between government, academia and industry, with special focus on GM crops, for example, Bt cotton and Bt brinjal. This chapter further argues if proper networking and interaction between these three actors namely, government, academia and industry is conducted it will have better adoption of agricultural biotechnology as well as it will lead to policy level changes required for GM crops. This chapter studies the politics embedded in the triple helix model of innovation in the context of GM crops and come up with policy implications required for the effective utilization of GM technology in Indian agriculture.

Scientists' Perception on GM Crops

The Department of Biotechnology (DBT), under the Ministry of Science and Technology, was established in 1986 as state developmental projects across a wide range of applications, like improving yield to combating diseases and nutritional deficiency. However, no genetically engineered crops had been successfully released from the public sector till 2015. China sought to actively promote private-public partnership in the case of GM crops, while in India a few MNCs have monopoly in the case of Bt cotton. This shows corporatization of GM crops in Indian agriculture. This leads to a monopoly of the private sector in the case of GM crops. As a scientist from University of Agriculture Science, Bengaluru suggests the involvement of public institution for the broader development of farmers as this will bring in together both the concepts of public welfare and commercial interest of the industry. There should be more networking between public and private sector that would benefit of both the sectors. This will result in commercialization and diffusion of GM crops. In the words of senior scientists of the University of Agricultural Sciences, Bengaluru:

> *Most of the companies are selling Gm technology. So we cannot depend on them but we should be ready with new technology along with indigenous technology. The public sector should come out so, that farmer will get cheap seeds.*

The commercialization of GM seeds is dominated by the private sector or seed companies. Owing to the involvement of private sector in the release and marketing of seeds by MNCs, the prices charged for the GM seeds are high. It is in this context it is advisable to make the involvement of public sector for the commercialization of seeds so that low price seeds will be available to farmers. In the process of developing modern varieties it is also argued that indigenous variety should be protected and we must not lose our indigenous variety because there are many indigenous varieties whose traits can be reused for the development of improved quality of seeds.

Table VI: Classification of Scientists working on Bt Cotton and Bt Brinjal (2000-2015)

Projects	**Scientists (N=81)**	
	Number	Percentage
Bt Cotton	24	29.6
Bt Brinjal	15	18.5
Both	12	14.8

Table VII: Scientists engaged in the projects on Bt Cotton and Bt Brinjal (2000-2015)

Number of Projects	**Scientists (N=81)**			
	Bt Cotton		**Bt Brinjal**	
	N	Percentage	N	Percentage
1-4	9	37.5	10	66.7
5-9	8	33.3	5	33.3
10-14	7	29.2	0	0.0
Total	**24**	**100.0**	**15**	**100.0**

The present study shows that 29.6 per cent of scientists are engaged in research on Bt cotton, while 18.5 per cent are engaged in research in Bt brinjal and 14.8 per cent of scientists are engaged in both Bt cotton and Bt brinjal research (see Table V). Around 37.5 per cent of the scientists working on project under Bt cotton are undertaking a project between 1 and 4, while 33.3 per cent of the scientists, 5-9, and 29.2 per cent of the scientists are working on projects under both Bt cotton and Bt brinjal (see Table VI).

Similarly, if we look at the number of scientists working on project on Bt brinjal then it is different story as compared to Bt cotton. This difference requires critical analysis as it shapes the implications of proprietary technologies and attitudes of scientific community on debated GM crops. Around 66.7 per cent of scientists are working on 1-4 projects on Bt brinjal, while 33.7 per cent are engaged in 5-9 projects on Bt brinjal. After critically analysing the data, it is also found that less number of scientists from the world of academia are engaged in research in GM crops.

The MNCs such as Monsanto working on Bt cotton collaborate with Indian seed company Mahyco. So, this is a private-private partnership on GM crops. This suggests monopoly of private companies in over GM crops in India. This also suggests areas in which networking has not evolved between public institutions on the one hand and private industry on the contrary. It was often argued that moratorium on Bt brinjal would hamper ongoing research in public-sector institutions on transgenic potato, tomato, rice, mustard, chickpea, groundnut and pigeon pea etc. the State's policy decision is not to allow GM crops, even field trials and declare a moratorium at least for the next 50 years (MoEF 2010). According to scientists included in the present study, conducting field trials require lot of time and money and both of which are not available, as nobody has adequate resources to invest in such controversial areas. Also whether such transgenic will develop into product and will be of use is another question. Thus in India politics of risk and safety have a major effect on the working of science and technology. This dichotomy between food and non-food crop as far as India is concerned suggests contested views and governance of science. When diffusion of agricultural biotechnology is considered, the State plays a non-significant role. Scientists under study suggest that Bt brinjal is already under cultivation illegally. This shows a lack of ability on the part of GEAC to control the illegal use of Bt brinjal. Also, Bangladesh has approved commercial cultivation of four open-pollinated varieties of Bt brinjal and Bangladesh is a neighboring state of India and open pollination is beyond the boundary of politics, governance or risk.

There is a mixed response from the scientific community on the release of Bt brinjal. According to a senior scientist from ICGEB, New Delhi:

> *As far as the case of Bt brinjal is considered it should not be banned if all the test is performed. When law is clear than why it is banned. We should not reduce the research and trials for coming years and subsequent field trials have been conducted and moreover Bt brinjal case study passed all the test and guidelines than why it is not allowed.*

The above statement suggests that the research and trials related to Bt brinjal is complete. Despite this, it is not allowed for the commercial release in India. One of the drawbacks in the case of science and policymaking in India is that the reports pertaining to field test of GM crops are not made public. This adds to the lack of trust in public with respect to GM crops. This suggests how fate of new technology is embedded with social, political, institutional and policy factors rather than the scientific factors. The moratorium on Bt brinjal is not affecting MNCs rather than Indian scientists who are ready with more than a dozen of GM crops such as chickpea, rice, wheat, mustard, etc. The MNCs like Monsanto are moving to other developing countries like Bangladesh and Pakistan for commercializing GM crops like Bt brinjal, Bt corn and Bt potato. It is argued that Bt brinjal can kill pests. It is a food crop. If consumed, it will have adverse effects on human and animal health. Thus, it is not safe to consume Bt food crop.

Policy level changes by the government are important as scientists are hesitant to work in the controversial areas like Bt brinjal and GM crops. According to a senior scientist of Bose Institute, Kolkata:

> *Policy level change is required. Unless it is properly designed there is no reason to work in such fields. Certain guidelines should be followed without proper guideline we cannot go for GM. India should not loose patentship, proper measures, proper guidelines everything is in writing but at field level it is not there.*

In the context of GM crops in India, the idea of public is more often absent in the realms of the triple helix, which calls for reflexivity beyond research laboratories. In this regard, many studies support the involvement of actors (civil society organizations, farmers, etc) in addition to the government, industry and academia networking of innovation.

Chapter V

Debating the Controversies: A Study of Agricultural Innovation System in India

The fifth chapter foregrounds the controversies embedded in the institutional mandates outlined to promote or restrict innovations in agricultural innovation system in India. Further, it discusses how the framing of public policy and networking between varied actors leads to transition in the modes of agricultural innovation system in India. Here the Public-Private Partnership (PPP) model is discussed in order to capture the process of knowledge creation from the stage of product development to diffusion of technology. In this chapter, the Scientific policy Resolution (1958), the Technology Policy Statement (1983), the Science and Technology Policy (2003) and the Science, Technology and Innovation Policy (2013) along with National Agriculture system, National Agriculture Policy (2000) and various initiatives of the Department of Biotechnology like Biotechnology industry Research Assistance Council (BIRAC) are discussed critically in order to study the underlying institutional mandates resulting into innovations in agriculture biotechnology. Understanding of the improved networking between varied actors like the government, academia and industry is required to develop R&D in agricultural innovation system in India, i.e how far the model of triple helix is relevant in present agricultural innovation system in India. The function of academia-industry networking can be performed by different institutional arrangements such as transfer offices, incubation, science parks, technology parks, startups, etc.

Role of Industry in Agricultural Innovation System in India

Scientific knowledge is distributed through value chain that includes universities, research institutions, private companies and foundations. Scientific knowledge and the associated technical artifacts lead to various form of intellectual property (Mansfield 1991).

Technology transfer from academia to industry is complex. Besides formal mechanism of patenting, informal mechanisms such as research collaboration, facility and credit sharing are on the rise. Informal mechanisms focus more on knowledge transfer. Innovation in agriculture results in intellectual property, land rights, commercialization of products, product development for the use of farmers and consumers. Improved interaction between these actors for the purpose of increasing the quality and type of interaction is necessary for the innovation within Indian agriculture. Indian agriculture research system is structured in such a way that it allows developing partnership and networking with multiple actors. In India as there is a constant effort to reach a tri-lateral or hybrid organizations in order to attract increased private investments in research, innovation and development. This can be captured in the words of a senior scientist at the National Centre for Biological Sciences (NCBS), Bengaluru: *"Industry has to undertake lots of expenses to test technology into field."*

When university, government and industry collaborate for a particular project it leads to a lot of significant advantages. If we look at this networking, from the perspective of university then hard work and expertise of scientists will be rewarded. If we analyze it from the perspective of the society, then the actual research will reach the field from laboratories.

Funding Mechanisms

There is chronic dearth of funding in R&D for agriculture and particularly in the basic research. Scientists included for the present study receive funding for their research activities from Department of Biotechnology (DBT), Department of Science and Technology (DST), Council of Scientific and Industrial Research (CSIR), Indian Council of Agriculture Research (ICAR)-Sponsored projects along with projects from a few international agencies. Triple Helix model III suggests that partnership of any two actors leads to something new. The active partnership of all three actors requires special expertise and is the most advanced stage of interaction. With the change in the role of universities, issues of intellectual property and technology transfer have become the goal of policy makers in universities, especially public universities like state and central universities in India. Scientists interviewed have also suggested that informal links are important to get funding for their research projects.

Another issue concerning funding for agriculture research is that often funding for project is of short duration and short span is not adequate to yield meaningful research outcomes. Projects are funded for the short duration which hinders the usefulness of projects. It is in this context that the government along with industry should support long term holistic project funds.

Funding often does not get disbursed at proper time and this has led to the completion of projects in a hurried manner due to which research result outcome get affected. Moreover, funding is not adequate. Funding for agriculture research has decreased significantly and this is low for basic research as compared to applied or developmental research work. The entire mechanism is not proper in developing countries such as India as compared to developed countries. Despite having limited resources, collaboration is encouraged where resources can be shared between larger groups of different geographical locations and institutional settings.

Bases of Selection of Projects

Interaction between scientists in the academia and industry may be strengthened by initiating joint projects mediated by the government which will bring together expertise of varied actors for the fulfillment of a common objective. Projects are selected by a joint project committee consisting of representatives from the Department of Biotechnology (DBT), International Society for Computational Biology (ISCB), and so on The selection is based on the relevance for the development of a specific institute or region as well the potential for technology transfer and future commercialization. Projects are usually set up jointly with the research institutions, industry, regulating state agencies, authorities dealing with safety measures and organizations, or individuals dealing with ethical questions.

Further the government may reexamine its institutional mandates to facilitate better collaboration between the industry and government. According to a senior scientist of MS Swaminathan Research Foundation (MSSRF) states:

> *Government can look at long term funding which have some proven quality because in three years they want to do something and another year they want to*

do some other thing. So, we do not provide stability and they all are lying with us. Three-year project terms are very short and it is very difficult to come up with meaningful results/products. One important ways to increase cooperation between applied and basic research is to develop collaborative projects particularly network projects involving scientists from different institutions, working in basic and applied research.

The long term collaborative project is required to increase interaction between scientists engaged in basic and applied research. Interaction between varied actors is required in research areas like biotechnology which is complex and uncertain. The DBT is active the collaborative projects, and has some programmes like Biotechnology Industry Partnership Programme & Small Business Innovation Research Initiative (BIPP&SIBRI), where public and private organizations are involved in collaborative projects. The main advantage of such collaborative projects between public and private sectors is how to develop products with a wider reach.

Mandates of Institutes

The mandates of the institute are significant in establishing collaborative ties between varied actors. They form the basis of collaboration between scientists of different institutes, and often guide the research activities of scientists. A university or research institutions will flourish and develop more if more scientists are working towards the mandates of the institutes. According to a senior scientist of Osmania University:

It all depends on the mandate of the institute. If some institute is there for providing services than naturally much R&D is not expected because they are service provider but that is one thing. Also mandate of the organization have to be research oriented than and only they will take the R&D forward and some time what happen the mandate is for example a college or university than they are just having educational objective than there also R&D cannot happen. If the mandate includes the policy which include the research and development will be carried out while making the R&D policy or mandate of the institutes.

The above statement reflects the traditional role of university and research institutions. Like universities are more inclined to teaching and research is somehow limited to the old traditional setting of university. Even at present state universities mandate is towards teaching and they are very less engaged in research activities. Also, these institutes lack equipment, infrastructure as their mandates do not allow so. Increased interaction among the scientists from basic and applied fields will increase the openness and confidence, which can increase cooperation.

Public-private partnership in Agricultural Innovation System

One of the knowledge flows in agricultural innovation system is the networking between public and private sector. The link between academia and private R&D is a valuable addition to any knowledge economy. This potential has been realized recently in India and the government is trying to connect the link between public and private sectors through various initiatives. Evidence suggests that rate of technical change and economic growth depended more on efficient diffusion (Freeman 1995: 10). Developing countries are the emerging centres of R&D collaboration. The transnational corporations are expected to add new innovative capacity bringing in new technology, global knowledge network and the resultant diffusion of knowledge.

Triple helix plays a crucial role in understanding the process of networking among various stakeholders in agricultural biotechnology. Networking between academia and industry is often initiated through government funded projects. Individual scientist plays a key role in facilitating such type of collaborative networking. In the case of GM crops private-private collaboration is still prevalent in India. Though laboratory level research has been underway for several other GM crops in universities and research institutions no major breakthrough in gm crop has been released by them. One of the advantages of triple helix is that academia and industry perform the role of the other. Industry undertakes the traditional role of teaching by providing internship and workshop to university and making them efficient to be occupied for the job. Similarly, the role of the university has transformed from teaching and research to being an entrepreneur where individual scientists are trying to form a networking with farmers and market. The networking between government, academia and industry can be seen for the training of professional who get employed at these institutes. Academia-industry networking is prevalent for the realization of commercial applicability of products as well as for field trials and field work. The traditional mode of the solving problem of the industry as a client is prevalent in universities, which helps in transferring products from laboratory to farm. Still triple helix I and triple helix II forms of knowledge production of the triple helix model are prevalent as far as the case of Bt Cotton is concerned. Even interaction between individual actors is not strong, while private industry is the active performer so far as the case of GM crops in India are concerned. Private-private partnership is still dominant in the case of Bt cotton involving industry from national to international origin. From organizational point, technical change is contingent upon internal organizational conditions and the relationship of organization to the receiver adding to their judgement of trust and reliability (Clark 2002). University collaboration with industry and government is limited as it provides graduates to industry and government. Research environment is not much developed in university setup in India. Industry lacks trust due to their orientation towards profit while government lacks confidence due to bureaucratic process.

Chapter VI
Conclusion

Chapter VI summarizes the findings of the study, dwells upon the limitations of the study and explores the scope of further research in the field.

Findings of the Study

The motivational factors which lead to the formation of collaboration between scientists are the complexity of research problems and machines used, rising cost of technological apparatus and research laboratory facilities, integrated expertise, the complexity of research problems and machines used, and so on.

Most of the scientists interviewed for the present study have not come across any such hindering policies and thinks it all depends on the mandates of the institute. The hindrances faced by the individual scientists can be manifold such as lack of understanding between the university and industry scientists. It also addresses bureaucratic process which exists in government organizations which makes collaboration process unnecessary long and hectic. It also addresses the chronic dearth of funds for agricultural research in general and for basic research specifically.

It is clear that government, academia and industry networking have not fully developed in case of agricultural biotechnology. There is more networking between universities or national research laboratories. For example, it is prevalent more between academia-academia, academia-industry and so on.

Networking with industry is adding a new dynamics to scientific research. This leads to the formation of contractual research within the realm of scientific research. Inter-individual collaboration appears to be more frequent than the other forms of collaboration like inter-institutional, inter-department, international, inter-continental and so on. Such higher frequency of inter-individual collaboration may be attributed to the relatively weaker institutional mandates in India. Interdisciplinary collaboration within India is more as compared to interdisciplinary collaboration abroad.

Scientists interviewed for the present study are engaged in projects with the DST, DBT, CSIR, ICAR and private industry like seed companies etc. and international collaborators. Most of the scientists interviewed collaborate with DST, DBT, and CSIR or with other state or central universities for projects with a less number of scientists working with industry or in collaboration with international organizations.

Research objectives of scientist varies depending upon the nature of institutes in which they are affiliated, and also depends on their networking partners with which they are engaged for a project. Off course individual interest guides the research problem undertaken by the scientist but it also depends on the rules and regulation of research grant, and policies of government bodies.

In India, triple helix I and triple helix II form of knowledge production is still more dominant as compared to triple helix III form of knowledge production. More private investment is needed. Private sector engagements into R&D are significantly lower than those in developed and other emerging economies.

With the advancement of modern science, the complexity of instruments has increased. This requires technicians/research professionals etc for the operation of the instruments and the government should increase the number of technicians for the operation of the instruments and machinery.

Scientists under study realized that there should be the forum which will bring scientists from academia and industry together. Even some of the initiative is undertaken by the government. But this type of collaboration v is less and limited to few institutes. This suggests that triple helix III will take the time to evolve.

It is observed how fear and unknowingness of technology can lead to discard of technology. A huge amount of public investment, time, scientific expertise, and so on are invested in developing any technology. So, decisions on GM crop or any controversial technology should take into account views of experts from academia, policy, scientific community, business to CSOs. Policy debate is very crucial for the development of research and development in agricultural biotechnology in India. The case of Bt cotton and Bt brinjal clearly depicts the lack of consensus on the part of state science.

The present study suggests policy suggestions to improve networking between government, academia and industry like increase R&D investment in basic research, increase participation of private sector in basic research, increase investment by private sector, exchanges of research personnel across government, academia and industry, increase in the number of long-term collaborative project, integration of varied discipline is significant to solve the challenge of modern day agriculture, attraction of funding through interdisciplinary research and competitive researchers and so on.

The conflict between industry and academia personnel can be avoided if proper MoU is signed in advance. Also, industry and university networking is more of contractual in nature and it is argued that short-term project is not useful in bringing meaningful results. Thus, there is a need to introduce long-term R&D projects by the industry to personnel as personnel in academia who are much interested in long-term projects. Resistance to change on the part of the university scientists may be attributed to their perspective on the functions of the university system, which emphasizes basic research and disciplinary education to the students.

Limitations of the Study

The present study is limited in terms of its scope. The study could not include other intermediary organizations which help in the commercialization or diffusion of technology. The study could not take the perspectives of farmers or policymakers or other potential actors like NGOs or civil society organizations in the study of networking between government, academia and industry. Industry personnel, to a large extent, could not be included. These limitations suggest that there is a methodological dictum in terms of time and space – coverage of various stakeholders within a stipulated period of time.

Scope of Further Research

The motivation of the industry to collaborate with academia and government research laboratories may be studied as part of rule-governed shared culture. This can add to more interests among scientists drawn from the academia collaborate with industry. Triple helix model of innovation is evolving in myriad forms in developing countries including

India. The model which exists in the West may not be suitable for Indian context. India has to evolve an independent model of innovation guided by an independent science and technology policy. The compliance with the international patent regime has not been able to create new vistas of knowledge production, for example, agricultural biotechnology, pharmaceutical biotechnology, and so on. The world of science must broaden its horizon to include the lowest denominators in the economy, culture and polity. In the present study, the farming community is often at the receiving end. Science as well as its practitioners must include the aspects of equity, democracy, sustainability, etc. while opting for a new technology.

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