GEOGRAPHICAL PROXIMITY AND ICT IN SCIENTIFIC COLLABORATION: A STUDY OF ENTOMOLOGISTS IN NORTH-EAST INDIA

Dissertation submitted to Jawaharlal Nehru University in partial fulfilment of the requirements for the award of the degree of

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Certificate

This is to certify that the dissertation entitled "**Geographical proximity and ICT in Scientific Collaboration: A Study of Entomologists in North-East India**" submitted by Sanghamitra Das in partial fulfilment of the requirements of **Master of Philosophy** of Jawaharlal Nehru University, has not been previously submitted for any degree of this university and this is her own work.

We recommend that this dissertation be placed before the examiners for evaluation.

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Contents

Chapter 1

Introduction

Over the past few decades, there has been a surge in the number of studies on scientific collaboration. Collaboration in and across scientific disciplines is an important mode of knowledge production and there are several studies in the literature that emphasize on this importance. It has been claimed by some authors that scientific collaboration is no longer "a neutral scientific practice" but has become "a scientific value" (Duque, et al., 2005). The authors who make this claim argue that the "necessity" and the "perceived success" of collaboration in basic science research (particularly in *high energy physics*), the increasing requirement for *larger and more complex instruments* and the importance of *informal communication* in the research process has led to a 'positive valuation' of collaboration. This has resulted in a scenario wherein, it is no longer necessary to justify collaboration as being productive for the production of new knowledge. But instead, collaboration has now become a "scientific good".

A large proportion of the literature on scientific collaboration highlights the advantages of collaborative practices, especially, with respect to publication productivity. There are studies which indicate that collaboration is directly associated with increased productivity in terms of published output (Katz & Martin, 1997; Beaver, 2001; Sonnenwald, 2006). However, this relationship between collaborative practices and scientific output is not well understood even in the developed world. This relationship has been verified to an even lesser degree in the developing countries. Despite this lacuna in thecomprehension of its benefits for publication productivity, collaboration in science is steadily on the rise. This suggests that the there are other factors which influence the actors' decision to collaborate, both at the individual as well as at the organizational level. This makes it all the more important to understand why scientists collaborate and the factors that affect the initiation and maintenance of scientific collaborations.

The present scholarship is a sociological study of the scientific activity of research collaboration. The aim of this chapter is to present a broad overview of the research undertaken in the present study. The first section outlines the conceptual framework within which the present study is based. This is followed by a brief description of disciplinary variation of scientific collaboration and the choice of the disciplinary background of the study. The relevance of the study and its research objectives, the methodology adopted, and the scopes and limitations of the study are discussed in the subsequent sections. The chapter ends by providing the chapterization scheme in the last section as a guide for the remainder of the thesis.

1.1. Geographical proximity, ICT and Scientific Collaboration

There are several factors that have an impact on scientific collaboration - geography, economic, socio-political and language (Katz, 1994) - and scientific factors, resource accessibility, social networks and personal factors (Sonnenwald, 2007). Of these, the factor of geographical proximity has been studied extensively in the literature on scientific collaboration. It has been shown that cooperation between scientists involved in a collaborative project decreases exponentially with the increase in the geographic distance between the collaborative partners (Katz, 1994). This finding has influenced a bulk of the empirical studies on the impact of physical distance on the process of scientific collaboration. However, with the improvements in transportation technologies and the advancements in communications technologies, physical space has become a relative phenomenon linked to economic costs and costs of time. Distance is now not only limited to the objective definition of space but the subjective perception of the ease of mobility between geographic locations (Moodysson & Johnsson, 2007; Torre & Rallet, 2005).

The advancements in information and communications technology (ICT) have had a profound impact on scientific research in contemporary times. The Internet and the electronic mail, or the email, are two such developments in communications technologies that have revolutionized the way in which scientific research is carried out. This is exemplified by the emergence of a new term in scientific collaboration called “collaboratories” (Sonnenwald, , 2007; Finholt, 2003). Collaboratories are laboratories without walls that enable scientists to collaborate across time and space through the use of ICT. Scientists can now access databases, complex instrumentation facilities, and research results from remote locations, enabling collaboration between scientists located at geographically dispersed regions.

These advancements in communications technologies are slowly changing the social organization in science, resulting in the democratization and decentralization of access to information (Zare, 1997; Finholt, 2003). This enables the process of knowledge production to move away from the historical "invisible colleges" comprising of a core of elite scientists working amongst themselves (Finholt, 2003) to a form of "distributed intelligence"(Zare 1997). The process of knowledge production can now involve scientists from peripheral institutions and locations allowing them to participate in cutting-edge research and contribute to the creation of novel scientific knowledge.

Collaboration across long distances through the utilization of the tools of ICT plays an important role in the integration of peripheral scientists. This form of collaboration makes it possible for scientists in developing countries to work with scientists in the countries of the developed world. It relies heavily on the advancements in communications technologies as tthe participants of this form of collaboration are not co-located. This means an increasing reliance on computer-based means of communication over face-to-face communication. However, it has been shown in the literature that communication through the computer cannot completely replace the need for face-to-face interactions (Rallet & Torre, 1999). Thus, a new concept of proximity called temporary geographical proximity (TGP), involving temporary collocation of collaborative partners, has emerged as an alternative mode to satisfy the requirements of physical proximity in long-distance collaboration (Torre, 2011).

Although the impact of geographical proximity and ICT on scientific collaboration has now been studied both in the developed and the developing regions, such a study has not been carried out in the peripheral region in India, namely, the North-East India. There are studies on the collaborative practices of Indian scientists in the south-western state of Kerala. However, it is difficult to generalize about the country as a whole owing to its size and socio-economic diversity (Duque, et al., 2005; Shrum & Campion, 2000). The process of knowledge production through collaboration is subject to various contingent factors or complexities that arise out of the local context of a region (Duque, et al., 2005). These factors that pose challenges to the process of collaboration vary across different regions in India. The present study is a maiden attempt at understanding how proximity and ICT affect the process of collaboration in a peripheral region of a developing country.

1.2. Disciplinary difference in collaboration

It has been found that the degree of scientific collaboration varies across scientific disciplines. This could be explained in terms of the difference in the nature of scientific fields. In investigating collaborative research practices within scientific communities, a disciplinary focus could provide a more in-depth analysis and a better understanding. It has been shown in the literature that scientists in the *biological sciences* tend to be relatively more collaborative than scientists in other disciplines (Newman, 2004; Fernandez, Ferrandiz, & Leon, 2016).This makes the choice of research areas in Biology well suited for conducting studies on scientific collaboration. It is on the basis of this empirical finding that the research area of Entomology, a branch of Biology which studies insects, was chosen for studying research collaboration among scientists.

1.3. The relevance of the study

The notion of proximity has a profound impact on the process of scientific collaboration. The different dimensions of proximity that have been defined in the literature are - *geographic, cognitive, institutional, organizational, social, economic, cultural* and *technological* (Boschma, 2005; Fernandez, et al., 2016; Knoben & Oerlemans, 2006). Although the definitions and the scopes of these dimensions sometimes overlap and their respective mobilizations are interlinked, the selective study of a single dimension could provide important insights into how a particular dimension of proximity affects the process of scientific collaboration and whether it is indeed important for scientific collaboration. It has been argued that geographical proximity is neither a necessary factor nor a sufficient condition for the process of learning and innovation (Boschma, 2005). It is also argued that developments in transportation and communications technologies are changing the meaning of physical distance(Torre and Rallet, Proximity and Localization 2005). ICT is also changing the way scientific research is carried out (Finholt, 2003; Walsh & Maloney, 2007). The present study aims at understanding whether these arguments hold true in a peripheral region of a developing country, i.e., the north-eastern region of India.

Studies conducted in the developing world on scientific collaboration suggest that scientists in developing countries are becoming increasingly collaborative (Sooryamoorthy, 2009; Duque, Shrum, Barriga Juniour, & Henriquez, 2009). Collaborative practices among Indian scientists have also been studied. However, these are limited to the specific location of Kerala

(Davidson, Sooryamoorthy, & Shrum, 2002; Shrum & Campion, 2000). The north-eastern region of India is geographically distant from the rest of the country and differs in terms of its history, culture and socio-economic development. The region has been least explored in relation to the production of scientific knowledge. Moreover, there has been no study on the collaborative practices of scientists located in this region. This scholarship is the first attempt at understanding if collaborative activities are undertaken by scientists in the north-east region, the patterns of collaboration that prevail in the region and whether or not geographical proximity shapes this pattern of collaboration. The perception about the role of the Internet in scientific research, especially in terms of mitigating the challenges of collaboration across large distances among entomologists in the region has also been explored in the present study.

1.4. Research Objectives

The first objective of this study is to understand the collaborative practices among a select community of scientists, namely scientists working in the area of Entomology, located in the geographically remote region of North-East India and also to determine whether geographical proximity has a role in shaping the patterns of collaboration in the region. The second objective of the study is to understand whether the recent developments in information and communications technology (ICT), like the Internet and the *electronic mail* or *email,* have helped scientists in this peripheral region to overcome the physical barrier of distance, thereby, affecting the patterns of collaboration in this region.

The study is intended to address the following research questions:

1. Do Entomologists located in the north-east region produce knowledge in collaboration?
2. What are the patterns of collaborations among the Entomologists located in the region?
3. Does geographical proximity influence the pattern of collaboration?
4. What is the role of ICT in forging long distance scientific collaboration?
5. Has ICT been successful in mitigating the challenges posed to non-collocated (or remote or geographically dispersed) collaboration?
6. How important do the scientists, specifically the Entomologists, think the advancements in ICT are for conducting collaborative research in this region?

These are some of the questions that the present study seeks to find answers to. The methodology adopted in conducting this research is described in the following section.

1.5. Methodology

The present study is an attempt in understanding the nature and the level of scientific activity, particularly collaborative activity, among Entomologists in a previously unexplored region. The scientists located in the north-eastern region of India have to face certain additional challenges in conducting research and development (R&D) activities, particularly collaborative research, owing to their geographic location. This study is a maiden attempt at studying research collaboration in this region. Hence, this study has adopted a *Descriptive* approach to explore a region that has not been studied in terms of research collaboration. Descriptive enquiry is also called *exploratory research* (Forcese & Richer, 1973)and its objective is to clarify and explore certain phenomena which have not been studied before and hence, no prior information is available about the phenomena (Forcese & Richer, 1973). Such studies are aimed at providing a description which gives new material and guidance for future research.

Furthermore, the study utilizes both *quantitative* and *qualitative* approaches of research. Quantitative research is based on parameters that can be measured or estimated and thus can be expressed in terms of quantity (Kothari, 1990). Qualitative research, on the other hand, is concerned with phenomena that can be evaluated in terms of their quality (Kothari, 1990). This includes attitude or opinion research which is meant to discover the attitudes and opinions of individuals or groups about a particular subject or institution (Kothari, 1990). The data collected in this study is obtained from both quantitative and qualitative methods. The quantitative method adopted in this study is the *bibliometric analysis* of co-authored publications obtained from the Scopus database. Scopus is a bibliographic database that contains abstracts and citations of scientific publication. It is also the largest database of peer-reviewed literature. It gives an overview of the world's research output in science, technology, medicine, social sciences, arts and humanities. This database is fairly comprehensive and includes journals that are widely subscribed world over (www.scopus.com). The qualitative method of enquiry employed in this study includes the *questionnaire method* which is utilized extensively in social science research. The two methods of data collection are discussed as below.

1.5.1. Bibliometric analysis: Estimating collaboration through co-authored publications

For decades, multiple-author publications, also referred to as co-authored publications, have been used as a basic counting unit for the measurement of collaboration (Katz & Martin, 1997). The papers written by more than one author are taken as an indicator of research collaboration and the bibliometric analysis of these papers gives rise to data that can indicate the trends of collaborative research in the time-period studied. However, recent literature has pointed to some notable drawbacks in this method for measuring collaborative activity which indicates that the measurement of co-authorship provides only a partial estimation of collaboration (Katz & Martin, 1997). Nevertheless, it is an important window into patterns of collaboration within a region.

In the Methodology section of the CWTS Leiden Ranking, under the sub-section of the Indicators are described **two counting methods** for estimating scientific activity in terms of publications (CWTS Leiden Ranking, 2015). The two methods are briefly described as below:

The impact indicators in the Leiden Ranking can be calculated using either a full counting or a fractional counting method. The full counting method gives equal weight to all the publications of a university. The fractional counting method gives less weight to collaborative publications than to non-collaborative ones. For instance, if the address list of a publication includes five addresses and two of these addresses belong to a particular university, the publication has a weight of 2/5=0.4 in the calculation of the impact indicators for the university. The fractional counting method leads to a more proper field normalization of impact factors and therefore to fairer comparisons between universities active in different fields. For this reason, fractional counting is the preferred counting method for the impact indicators in the Leiden Ranking. Collaboration indicators are always calculated using the full-counting method.

This study utilizes the full counting method for counting the instances of collaborations. The full counting method is prevalent in the related literature for estimating research collaboration (Newman, 2004; Fernandez, Ferrandiz, & Leon, 2016). The data was collected from the Scopus database using a combination of the following key words pertaining to papers published in the discipline of Entomology, originating in the north-eastern region of India- *entomology, insect science, medical entomology, economic entomology, pest control, forest entomology, insect genetics, insect molecular biology, insect biochemistry, sericulture, insect systematics*. The search was carried out for a period of forty one years, from 1975 which the first instance of a collaboration included in the Scopus database to the present year, until the last month of data collection. This was carried out between the months of March and May, 2016. The data collected was subsequently analyzed, manually, to identify the patterns of collaboration prevailing within the region.

1.5.2. The Questionnaire method

In addition to the full counting method for counting co-authored papers for estimating the degree of collaboration, the present study also employs the questionnaire method of data collection for qualitative assessment of collaborative practices among Entomologists in the north-east region. This is done through the use of e-mail questionnaires. The questionnaire method was adopted to find out the opinions and the attitudes of the Entomologists based in the north-eastern region towards the use of the Internet and the *world wide web* for research and development activities (R&D), particularly in collaboration across long distances. The questionnaire method was used to conduct attitude or opinion research. The questionnaire method was chosen as this study is a preliminary inquiry into the collaborative patterns of Entomologists within the region. This method was chosen also because the conducting of face-to-face interviews in a region as expansive as the north-east requires more time and resources than was permissible within the scope of this study.

A questionnaire consists of a definitive number of questions printed in a definite order in a form or a set of forms (Kothari, 1990). The questionnaires are then mailed to the respondents and the respondents are expected to read and understand the questions and provided responses in the space provided within the questionnaire (Kothari, 1990). The respondents are expected to fill the questionnaires on their own. There are two types of questions that are included in a questionnaire- *structured* or *open-ended questions* and *unstructured* or *close-ended questions* (Forcese & Richer, 1973). In structured questions the possible responses are pre-determined and provided in the questionnaire. In the case of unstructured questions, the respondent is allowed to write whatever they desire in a space provided in the questionnaire. Structured questions are used when the researcher has a fair idea of the possible responses to a particular question (Forcese and Richer 1973). This limits the scope of response among the respondents. Unstructured questions allow the respondents th freedom to express themselves, keeping the questions free of *a priori* assumptions (Forcese & Richer, 1973).

The questionnaire method for the purpose of the present study employed an e-mail questionnaire. The e-mail questionnaire was created electronically using the Google Forms application. This e-mail questionnaire included both structured and unstructured questions. Questions were related to assess the attitudes of the Entomologists in the north-eastern region of India regarding the use of the Internet and the internet based means of communication for collaborative research, especially in the case of non-collocated collaborations. The questionnaire also included questions which attempted to find out the attitudes of the scientists towards the use of computer-mediated communication (CMC) and their opinions on the use of CMC over face-to-face communication with collaborative partners. The e-mail questionnaire was mailed through electronic mail to fifty four (54) Entomologists working in the various research institutions in the north-east region. The e-mail addresses and telephone numbers were obtained through the institutional websites and the Scopus database. There were sixteen (16) valid responses received, giving a response rate of 29.63%, approximately thirty percent (~30%).The responses obtained were then analyzed to understand the level of internet use in collaborative research activities within the region.

1.6. Scopes and limitations of the study

The present study based in a peripheral region of India. This makes the choice of location most conducive to the study of the geographical dimension of proximity. How distance affects collaborative research in the context of a developing country is an important analysis and has the potential to provide important policy implications for fostering collaborative research in the developing world.

However, as already mentioned, the study of collaboration using co-authorship data from bibliometric databases can only provide a partial estimation of the degree of collaboration. This is due to two important reasons. First, all collaborative project do not culminate into published outputs. It has been shown in the literature that there are certain extrinsic motivations for collaborations, especially in the "resource constrained" developing world. For this reason, the self-reported method of measuring collaboration gives a more precise estimate of the degree of collaboration of a scientist. Second, the Scopus database is not inclusive of several local Indian journals which are not listed in the international database for several reasons of standards. Hence, a more comprehensive and robust estimation can be generated by analyzing the publications in the relevant local journals. This opens up scope for further research in the area.

Another limitation of the methodology pertains to the use of the questionnaire method for collecting qualitative data. Although, the questionnaire utilizes both structured and unstructured questions, a more in-depth analysis is required in order to understand how scientists in a peripheral region adopt and utilize latest technological advancements in conducting their research. Although the present study is a preliminary enquiry into a previously unexplored area, the study needs to be followed up by more detailed and rigorous methods of inquiry.

1.7. Chapter scheme

The remainder of the thesis is structured as follows. Chapter 2 deals with the review of related literature. This includes literature on scientific collaboration, proximity dimensions and the impact of geographical proximity on the process of scientific collaboration. Chapter 3 is the chapter on the impact of the internet technologies on scientific collaboration, especially on long-distance collaboration. This chapter also discusses how the revolutionary developments in communications technology are gradually resulting in the change in the social organization of science. The notion of TGP has also been explained in this chapter. The background of the study is developed in Chapter 4 which explains the choice of the discipline and the location for the present analysis. Chapter 5 gives the empirical findings from the study that investigates the pattern of collaboration among entomologists in the north-eastern region. In addition to this, the chapter states the findings from the opinion research which aims to understand the perception of the Entomologists on the use of the internet for scientific research. Lastly, Chapter 6 gives the conclusion of the research.

Chapter 2

Review of Literature

The process of scientific collaboration has evoked considerable interest in the sociological studies of science. Over the past few decades, there has been an increasing interest among the Science and Technology Studies (STS) scholars to study the phenomenon of scientific collaboration. The process of scientific collaboration has also been discussed in other disciplines which include information science, psychology, management science, computer science, sociology, research policy and all other disciplines concerned with the collaborative mode of knowledge production (Sonnenwald D. H., 2007). There is a plethora of literature related to scientific collaboration ranging across all of the above disciplines. This indicates the scope and diversity of the topic, as well as the significance and relevance of collaboration in research and development (R&D).

Scientific collaboration is a dynamic process and there are several aspects to this notion (Sonnenwald D. H., 2007). The literature on scientific collaboration is as diverse in its approach as it is expansive. In studying scientific collaboration, there is a need for STS scholars to narrow down their approach to address specific aspects of the process of collaboration which in turn contributes to its holistic understanding. The present study aims at investigating two important factors that affect the process of scientific collaboration - the geographical dimension of proximity, and the developments in information and communications technology (ICT). This chapter provides a review of the related literature on scientific collaboration. The different dimensions of proximity and their dynamics are discussed in order to understand how a single dimension of proximity may affect the process of scientific collaboration. The advancements in transportation and communications technology have changed the meaning of physical distance. How the recent developments in ICT impact the process of scientific collaboration by facilitating communication across large distances is also discussed in this essay.

The chapter begins by discussing the process of scientific collaboration, its scope and importance, and the factors that affect this process. The next section describes the different dimensions of proximity with a special emphasis on the geographical dimension of proximity. The final section deals with the impact of the advancements in ICT, like the Internet and the *World Wide Web*, on scientific collaboration, specifically on collaboration across large distances.

2.1. Research collaboration in Science

Scientific collaboration has increased in incidence and importance over the recent decades. There are several scholarships that indicate the growing trend of scientific collaboration across disciplines (Cronin, Shaw, & La Barre, 2003; Wagner & Leydesdorff, 2003). This trend is more prevalent in the natural sciences as compared to the social sciences (Sonnenwald, 2007; Cronin, et al., 2003). One possible reason for this difference could be the absence of an operational paradigm in the social sciences (Crane, 1972). In the absence of an established paradigm, consensus on the importance of a research problem and the methodology best suited for investigating a problem cannot be conveniently arrived at making it difficult for researchers to co-operate and hence, collaborate with one another in the social science disciplines.

The increase in the frequency of research collaborations in science is an interesting development and has been investigated in a number of studies. It has been shown that scientific collaboration began growing in numbers around the turn of the twentieth century (Cronin, et al., 2003; Adams, et al., 2005). There has been a shift in the focus from research carried out by single investigators to research carried out collaboratively involving many scientists from different institutions and diverse disciplines. There are several factors that have led to this development. Some authors argue that the nature of science itself has changed over the years as the scale and complexity of research has grown to such an extent so as to favor collaborative research over “single investigator scientific research” (Cronin, et al., 2003; Sonnenwald, 2007). Other authors suggest that social, political and economic factors have also played a role in the growth of collaborative research over the years. This section discusses the literature on scientific collaboration, the factors that affect this collaborative process and the factors that affect it in the context of the developing world.

2.1.1. Understanding scientific collaboration

As indicated earlier, there are several approaches to the study of scientific collaboration. For instance, scientometric studies the patterns of collaboration using quantitative methods such as co-authorship statistics whereas, the study on how information and communications technology (ICT) impacts collaboration comes under the ambit of computer-supported co-operative work and social informatics (Sonnenwald D. H., 2007). However, in order to fully comprehend this multi-faceted topic we must first understand what constitutes research collaboration.

The term, *scientific collaboration,* has been defined by several authors in different scholarships. Ynalvez and Shrum have defined scientific collaboration as a "close interaction between two or more scientists in a research project with one or more specific goals" (M. A. Ynalvez, W. M. Shrum, 2011). These goals may also include the "simple goal" of "resource acquisition", in addition to the fulfillment of specific objectives. Sonnenwald has defined scientific collaboration in terms of human behavior, tasks and social contexts of science (Sonnenwald D. H., 2007). According to the Sonnenwald, scientific collaboration is a human behavior between two or more scientists which facilitates the "sharing of meaning" and the "completion of tasks" with respect to a common goal and which takes place in specific social settings (Sonnenwald D. H., 2007). In simple terms, scientific collaboration can be defined as the interaction between two or more scientists who work together to achieve a common goal or objective. However, this naturally gives rise to the question of how closely must two researchers work in order to constitute a 'collaboration' (Katz & Martin, 1997).

Drawing from this question, Katz and Martin have attempted to define collaboration in terms of the researchers involved. They have proposed some "putative criteria" for distinguishing "collaborators" from other researchers. These include scientists who make substantial contribution to the research project throughout or for a large part of its duration, the scientists whose names appear in or who proposed the original research proposal, those responsible for one or more main elements of the research and those responsible for a key-step in the project. However, as also expressed in the paper, an exact definition of research collaboration is difficult to arrive at as it is impossible to clearly demarcate between informal interactions and formal collaborations. It also cannot be overlooked that more often than not, informal interactions lead to formal scientific collaborations, and that a casual conversation can lead to path-breaking new ideas. Thus, although a clear cut conception of research collaboration is difficult to formulate, a general idea can be drawn from the literature so as to have a broad understanding of the term.

2.1.2 The stages of scientific collaboration

In her 2007 paper, Diane Sonnenwald has described the process of scientific collaboration by illuminating four stages of scientific collaboration – foundation, formulation, sustainment and conclusion (Sonnenwald, 2007). These stages were highlighted to indicate the complexity of scientific collaboration. These stages enumerate the factors that arise out of each respective stage and which have an impact on the collaborative process. The different stages of collaboration and the factors that emerge are discussed as follows.

Foundation Stage

The foundation stage is the initial stage of the collaborative process which is concerned with the factors that are required for the consideration of collaboration. These factors determine whether or not collaboration takes place. These factors include scientific, political, socio-economic, resource accessibility, and social networks and personal factors.

Formulation stage

This stage involves factors that determine the initiation and planning of collaborative research projects. The process of scientific collaboration entails certain additional requirements of planning and time for planning. The factors that arise in this stage include research vision, goals and tasks; leadership and organization structure; use of information and communications technology (ICT); and intellectual property rights and legal issues. These factors require additional time for management in order to achieve success in collaboration.

Sustainment Stage

After the initiation of a collaborative project, the collaboration needs to be sustained for the duration of the project in order to achieve the goals of collaboration. During the course of the collaboration, several challenges might arise. The following factors affect this stage. The evaluation of the organizational structure and the tasks allotted, communication and the process of learning.

Conclusion Stage

The conclusion stage is concerned with the termination phase of the collaboration process. This stage involves the factors of that are concerned with the results that emerge form the process of the collaboration. This stage includes factors like definitions of success and the dissemination of the results of the collaborative project. The results of a successful collaborative venture include the creation of new scientific knowledge, increase in publication and citation counts, acquiring of new knowledge and skills, educational results that include completion of educational programs, change in administrative systems and practices and the creation of administrative tools and the improvement of existing tools. Dissemination of results includes co-authorship of publications and presentations.

2.1.3. Types of scientific collaboration

Scientific collaboration is a complex process. There are several ways in which collaboration between units occurs. Several approaches to the classification of scientific collaboration emerge in the literature. This section classifies collaboration on the basis of two such approaches; classification with respect to the social context of science, and classification in terms of the unit of collaboration.

A. Classification with respect to the social context of science

Science is a social institution and scientific collaboration takes place within the larger social context of science (Sonnenwald D. H., 2007). These social contexts are often used in the literature to classify collaboration on the basis of discipline, geography and organizational structure (Sonnenwald D. H., 2007). A brief outline of these categories of classification is as follows.

Disciplinary focus

The disciplinary distinction of collaboration are characterized by the terms, **intra-**, **inter-**, **cross-**, **multi-** and **trans-disciplinary collaboration**. These terms emphasize on the disciplinary knowledge that is incorporated into and produced from the process of the scientific collaboration. **Intra-disciplinary** or disciplinary collaboration takes place within the framework of the same discipline. **Inter-disciplinary** collaboration involves incorporation of knowledge from across disciplines.

The terms **multi-** and **cross-disciplinary** collaboration are used interchangeably with inter-disciplinary collaboration, However, many authors distinguish multi-disciplinary collaboration from inter-disciplinary collaboration on the grounds that in multi-disciplinary collaboration, although the knowledge base from two or more disciplines are utilized in the collaboration process, these different knowledge bases are not integrated or synthesized. An example includes the use of methods or scientific instruments originating from a particular discipline to investigate research problems in a separate discipline.

Trans-disciplinary collaboration involves the integration of expansive knowledge bases relevant to a particular problem in order to find solutions to the problem. This may include the knowledge base from natural sciences, social sciences and humanities. This is also sometimes referred to as the **mode 2** knowledge production.

Geographical focus

This classification is made in terms of the geographic location of the scientists participating in a collaboration. This includes **remote collaboration, distributed collaboration, scientific collaboratories** and **international collaboration.**

Remote and **distributed collaboration** refer to the type of collaboration which involve participants in geographically distributed locations, i.e., scientists who are not collocated.

Scientific collaboratories include collaboration in through a network-based facility that utilizes the advancement in information and communications technology (ICT) to connect participants across time and space by providing remote access to data, tools and scientific instruments. **International collaboration** is concerned with the participation of scientists belonging to different nationalities working together to achieve common objectives. This form of collaboration can be considered as a special form of remote collaboration.

Organizational focus

This type of collaboration takes place across organizational settings. This may include collaboration across geographical distances but its main focus is on the factors that emerge as result of differences between academia and business, government and non-government organizations including communities.

A. Classification at the level of the unit of participation

The second approach to the classification of collaboration is at the level of the unit of participation (Katz & Martin, 1997). This classification includes collaboration at the individual, group, departmental, institutional, sectoral and the national level. Collaboration at the individual level is the fundamental unit of collaboration. Collaboration between groups involves collaboration within a department. Departmental collaboration includes collaboration between departments in the same instiution, Institutional collaboration involves collaboration between two or more institutions. Sectoral collaboration comprises of collaboration between institutions of different organizational settings. Finally, the collaboration at the level of nations includes institutions in different countries.

The classifications of scientific collaboration discussed so far make it easier for scholars to understand the complexities of the process of collaboration and are helpful in determining the different factors that affect the process of scientific collaboration.

2.1.4. Significance of scientific collaboration in terms of publication productivity

It is a popular assumption that productivity and scientific collaboration are positively correlated. As has already been mentioned, a substantial amount of literature indicates that scientific collaboration is associated with high productivity in terms of published output (Katz & Martin, 1997; Pravdic & Oluic-Vukovic, 1986). Publication productivity is mostly measured in terms of published papers and is also considered an important aspect of research productivity (M. A. Ynalvez, W. M. Shrum, 2011). The number of publications of a scientist is very commonly taken as an indicator of personal merit (M. A. Ynalvez, W. M. Shrum, 2011). Moreover, it has been found that the effect of collaboration on productivity depends on the types of links between scientists (Pravdic & Oluic-Vukovic, 1986). This study suggests that collaboration with high-productivity scientists tends to increase personal productivity whereas links with low-productivity scientists tends to decrease personal productivity. The promotion of scientific collaboration in the developing world is based on this positive relationship between scientific collaboration and publication productivity. However, in a study conducted on resource-constrained institutions in a developing region, it has been shown that scientific collaboration has no direct association with publication productivity, both in local and foreign publication outlets (Ynalvez & Shrum, 2011). The findings on the relationship between scientific collaboration and publication productivity are not uniform across the developed world, as well. In a study on the Italian academic research system, it has been found that there is no direct co-relation between scientific collaboration and publication productivity (Abramo, D' Angelo, & Di Costa, 2009). This naturally gives rise to one important question-in the absence of a direct relationship between scientific collaboration and publication productivity, what are the factors that motivate scientists to collaborate?

In the developed as well as the developing regions, collaborations do not always necessarily result in publications. Publication output may not be as important a factor in attracting researchers to form collaborations. In the context of the developing world, in this case the Philippines, collaborations offer certain extrinsic rewards more attractive than the publication of research results (M. A. Ynalvez, W. M. Shrum, 2011). These include opportunities for domestic and foreign travel, supplementary income and increased esteem among peers. These findings indicate the need to re-evaluate the relationship between publication productivity and scientific collaboration in both the developed and the developing world.

2.1.5. Scientific collaboration in the developing world

The review of the literature thus far has been mostly based on investigations in the advanced countries of the developed world. In the developing countries, the few studies that have been conducted suggest that the realities pertaining to the process of scientific collaboration are quite different from those in the developed world. It has been discussed in the literature that in addition to the benefits, scientific collaboration entails certain individual and collective costs (Katz & Martin, 1997). In order for a collaborative project to be successful, a balance between the potential benefits and costs of collaboration must be achieved. In the case of the developing countries, it is this balance that is often elusive and the costs pertaining to collaboration far outweigh the benefits that are associated with it (Duque, Ynalvez, Sooryamoorthy, Mbatia, Dzorgbo, & Shrum, 2005). However, despite these challenges, scientists in the developing world have been shown to have become increasingly collaborative over the years (Sooryamoorthy, 2009). This implies that the collaborative mode of knowledge production is an important scientific activity also in the global south.

The process of collaboration involves activities like interaction, communication and information exchange, which require a lot of coordination and hence, a considerable amount of time and energy (Duque, Ynalvez, Sooryamoorthy, Mbatia, Dzorgbo, & Shrum, 2005). The scientists in the developing world may not have adequate and sufficient resources to maintain such relationships over time and distances. Furthermore, it has been shown that collaboration in the developing world is subject to certain contingent problems that arise out of the local context of the region (Duque, et al., 2005; Shrum, 2005).Thus, the process of collaboration in developing countries is subject to challenges that are specific to the geographic location of collaboration and are difficult to foresee without adequate knowledge of the dynamics of the local institutions (Duque, Ynalvez, Sooryamoorthy, Mbatia, Dzorgbo, & Shrum, 2005). The same study discovered that these contingent problems also affect scientists who are not engaged in collaborative activity in, more or less, the same way that they affect the scientists are involved in collaborative research. This strongly suggests that the process of collaboration and the resulting generation of novel scientific knowledge vary between the developed and developing countries depending on the social, political and economic conditions of the region.

These studies based in the developing world were conducted almost a decade ago and give a rather pessimistic account of the possibility of collaborative research in the developing regions. The more recent studies indicate that scientists in the developing world, including India, are participating to a greater extent in the production of novel scientific knowledge despite the problems that arise out of their local contexts (give reference). Scientists are expanding their professional networks to include colleagues in the developed world. In the 1960s, two scholars had identified the problem of the "isolation" of scientists in the developing world (Dedijer, 1963; Salam, 1966). The problem of "isolation" suggests that scientists in the developing countries are isolated from scientists in the developed countries and also from each other. However, the increase in the instances of scientific collaboration from the developing world is an indication that this "isolation" is no longer heavily imposed on the scientists in the developing countries. The main aim of the present study is to identify the factors that have resulted in, as well as will enable further, the integration of developing countries scientists into the international scientific community leading to the democratization and decentralization of the process of knowledge production and information access.

2.1.6. Factors affecting scientific collaboration

Scientific collaboration is a complex and a dynamic process. Although the basic tenets of conducting research in a collaborative project remain the same as in the case of single investigator research, collaboration requires some additional planning and additional time for planning (Sonnenwald D. H., 2007). There could be as many types of interactions between scientists as there are scientists and any number of them may lead to or inhibit a collaborative endeavor. From the literature reviewed thus far, some of the key factors that affect collaboration have been enumerated.

Factors motivating scientific collaboration

Listed below are a few of the important factors that motivate collaboration (Sonnenwald, 2007; Katz & Martin, 1997; Katz, 1993):

- changing patterns of funding
- the rising costs of conducting fundamental research
- the ease and accessibility and fall in the cost of travel and communication
- forming professional networks in the form of formal and informal interactions with colleagues
- increasing specialization within scientific fields and the emergence of 'big science'
- the growing importance of inter-disciplinary fields which integrates knowledge from several disciplines
- scientific popularity, visibility and recognition
- rationalization of scientific manpower
- sharing knowledge, skills and techniques
- transferring tacit knowledge
- intellectual companionship
- increasing cross-fertilization of ideas
- socio-political factors

There could be several other factors that can contribute to the success of a collaborative project. However, these are some of the fundamental factors that must be kept in mind while studying scientific collaboration.

Factors inhibiting collaboration

There are many challenges that have to be overcome while initiating and sustaining a collaborative project. Some of these factors are discussed in this section of the study.

Firstly, in relation to financial costs, although collaborations reduce certain operational costs there are some additional costs that have to be dealt with (Katz & Martin, 1997). These include transportation of researchers and equipments across dispersed geographic locations, as well as technical personnel.

Secondly, it includes costs in terms of time(Katz and Martin 1997). As mentioned earlier, scientific collaboration comprises additional planning and hence, additional time in making these plans (Sonnenwald D. H., 2007). These include time for preparing a joint proposal, jointly defining the research problems, clearly defining and communicating research visions, goals and tasks, and resolving of any disagreements that might develop through the course of the project (Sonnenwald, 2007;Katz & Martin, 1997). These costs are aggravated if collaboration is to be carried out between scientists who are geographically dispersed or not collocated.

Thirdly, collaboration brings about the incidence of increased administrative management (Katz & Martin, 1997). When several scientists and many institutions are involved, research requires greater management. If collaboration is carried out over large distances, this adds to the problem of management. A more formal management could mean decreased flexibility in terms of creativity of the researchers.

There could be as many factors affecting the process of collaboration as there are forms of interaction between scientists. However, the factors listed above are the most important factors found in the literature. The notion of proximity plays a vital role in the process of collaboration. However, proximity is not always defined in terms of spatial distance. The different dimensions of proximity that emerge in the literature are discussed in the subsequent section.

2.2 The different dimensions of proximity

Proximity plays an important role in the process of knowledge production and innovation (Boschma, 2005).In the late 1990s, *the French School of Proximity Dynamics*, made a pioneering contribution to the notion of proximity by proposing that proximity comprises of dimensions other than just geography (Boschma, 2005 ; Fernandez, et al., 2016). Over the years, the concept of proximity has been used in different ways in the literature and the definitions and measurements of the different dimensions of proximity are sometimes contradictory and often show a great degree of overlap (Knoben & Oerlemans, 2006; Boschma, 2005). There are eight dimensions of proximity that emerge in the literature- geographic,cognitive, institutional, organizational, social, economic, cultural and technological proximity (Boschma, 2005; Fernandez, et al., 2016; Knoben & Oerlemans, 2006). It has been shown that the different dimensions of proximity play significant roles in shaping scientific collaboration (Fernandez, Ferrandiz, & Leon, 2016). Thus, it becomes imperative to provide clear definitions of these dimensions so as to be able to isolate the impact and relevance of these dimensions to the process of scientific collaboration. The various dimensions of proximity are defined as follows.

Geographic proximity

It has been shown in the literature that geographic separation between collaborators has a negative effect on scientific collaboration (J.S.Katz, 1994). The development of information and communications technology (ICT) ushered the hope that physical location would no longer be a barrier to the exchange of information and this would lead to an increase in the diversity of geographic locations in collaborative projects (Beaver, 2001). However, recent studies in the developing world have shown that ICT has not been able to address the challenges that collaboration across distances entail (Duque, Ynalvez, Sooryamoorthy, Mbatia, Dzorgbo, & Shrum, 2005). This indicates that geographical proximity is still a factor that has considerable relevance in scientific collaboration.

Cognitive proximity

Cognitive proximity is the knowledge base shared between organizations which facilitate transfer of knowledge by developing “absorptive capacity”, enabling the actors to perceive, identify, acquire, comprehend and utilize knowledge available from others (Fernandez, Ferrandiz, & Leon, 2016). A certain degree of cognitive distance is important in order to improve the knowledge base. However, the challenge is to ensure diversity in sources of knowledge in order to generate diverse complementarities while ensuring that the actors have a similar frame of reference (Fernandez, et al., 2016; Knoben & Oerlemans, 2006).

Institutional proximity

Institutional proximity is the degree of similarity between formal institutions like laws, rules and regulations, and informal institutions, like cultural norms and habits, which may be instrumental in facilitating flow of knowledge by enabling trust and reducing uncertainty and risks (Boschma, 2005; Fernandez, et al., 2016). Institutional proximity is often based on similarities between the institutional framework of countries and regions which influence the ways in which actions are coordinated(Knoben and Oerlemans 2006).

Organizational proximity

Organizational proximity pertains to the extent of similarities between organizational arrangements, either within or between organizations(R. Boschma 2005). It also includes the extent to which relations are possible between the actors within or between organizations(R. Boschma 2005). It involves the rate of autonomy and the degree of control in organizational settings. A certain degree of organizational proximity is required in order to reduce the uncertainties pertaining to the process of knowledge production through collaborations(Fernandez, Ferrandiz and Leon 2016).

Social proximity

It has been shown in the literature that social proximity facilitates scientific collaboration(Fernandez, Ferrandiz and Leon 2016). Social proximity is based on socially embedded relations of friendship, kinship and past experiences between actors that stimulates interactive learning due to increased trust and commitment (Boschma, 2005; Knoben & Oerlemans, 2006). Social proximity plays an important role at the initiation of a collaboration and is generally measured through prior collaborations or previous research experience(Fernandez, Ferrandiz and Leon 2016).

Economic resources

It has been shown in the literature that having economic resources impact scientific collaboration. The geographic areas which have similar levels of resources dedicated to research and development are more likely to foster collaborations between themselves(Fernandez, Ferrandiz and Leon 2016). This concept is derived from the centre-periphery hypothesis applied to research collaboration. According to this hypothesis, differences in economic resources among geographical areas determine the spatial patterns in scientific collaboration. Economic resources could be represented by an agglomeration or a geographic location which provides greater ease of achieving organized proximity through the use of infrastructures and institutions (Torre and Rallet, Proximity and Localization 2005).

Cultural proximity

Cultural proximity can be analyzed at two different levels- the first analysis it is assumed that organizations within the same geographical region share the same culture, and the second level of analysis takes into consideration differences in organizational culture between collaborating partners(Knoben and Oerlemans 2006). Both forms of analysis indicate that cultural proximity facilitates the interpretations of actions on the part of the collaborators and makes "smoother" the process of collaboration. Cultural proximity could be included under the informal type of institutional proximity(R. Boschma 2005).

Technological proximity

Technological proximity is based on shared technological capabilities and knowledge bases(Knoben and Oerlemans 2006). Technological proximity facilitates the process of collaboration by increasing the absorptive capacity, which is the ability to assess the value of new external knowledge, assimilate it and apply it for commercial benefits. An organization with a certain absorptive capacity can learn from all other organizations equally(Fernandez, Ferrandiz and Leon 2016). Technological capacity refers to the learning process between actors or collaborators and deals with the content of the knowledge being exchanged and the value of these exchanges. This is similar to cognitive proximity (Boschma, 2005; Torre & Rallet, 2005).

Although the different dimensions of proximity have come to be defined and determined in discrete terms, their mobilizations remain interconnected (Torre, The role of proximity during long-distance collaborative projects. Temporary geographical proximity helps 2011). The dimensions of proximity do not function mutually exclusive of one another but are capable of substituting or complementing other forms of proximities (Boschma, 2005; p. 62). It thus becomes necessary to understand the relations between the different dimensions in order to determine how a particular form of proximity affects the process of knowledge production and innovation. The relations between the different dimensions of proximity are discussed in the following section.

2.2.1 The relations between the different dimensions of proximity

The relations between the various dimensions of proximity have been analyzed in one of the pioneering works on proximity. Ron A. Boschma in 2005 examined the role of proximity in the processes of innovation and knowledge production in his paper (R. Boschma 2005). In this paper, the author argues that the significance of geographical proximity for the process of knowledge creation cannot be analyzed in isolation but must be examined in relation to the other dimensions of proximity. The paper discusses five different types of proximities – cognitive, organizational, social, institutional and geographical proximity and the relations between them. These are briefly discussed as follows.

As has already been discussed in the previous section, the cognitive dimension of proximity is concerned with the knowledge base shared between organizations facilitating the effective transfer of knowledge. A shared knowledge base helps in acquiring a similar frame of reference with respect to scientific knowledge, thereby making it easier for actors to initiate and maintain relations and carry out communication with each other (Moodysson & Johnsson, 2007; p. 120). However, in the paper being discussed, Boschma argues that excessive cognitive proximity is detrimental to the process of knowledge creation and innovation. This is because knowledge creation often requires expertise in diverse and complementary bodies of knowledge. A certain amount of cognitive distance enables the exchange and cross-fertilization of ideas. Excessive cognitive proximity can also result in cognitive lock-in, making actors and organizations unreceptive to new information, technology and markets. In order to overcome these challenges posed by too much cognitive proximity, the author suggests the requirement of geographical clusters. Geographical clusters comprises of actors with a common knowledge base but diverse and as well as complementary knowledge resources. In geographical clusters, the costs of coordination are low which in turn encourages specialization. Thus, geographical clusters enable enough cognitive proximity for effective communication and at the same time, encourage competition and specialization among local actors to ensure novelty of innovation.

Although a shared knowledge base is a prerequisite for effective knowledge transfer, this is also dependent on the capacity to co-ordinate activities and share complementary sets of knowledge (R. Boschma 2005). Organizational proximity helps in the co-ordination of the exchange of information among actors within and between organizations by facilitating the establishment of relations. However, too much organizational proximity can result in a lock-in to limit exchanges to specific relations. Knowledge creation is always accompanied by risks and uncertainties. In order to reduce risks and manage uncertainties, strong regulatory and control mechanisms are required to ensure intellectual property rights and suitable reward systems. These mechanisms require a hierarchical organization. However, the disadvantages of a hierarchical organization are the lack of feedback mechanisms resulting in an absence of interactive learning, and the lack of organizational flexibility to foster innovations. The problems of organizational proximity can be solved through the establishment of loosely coupled organizations. Loosely coupled organizations are organizations characterized by weak ties between organizational autonomous actors. This ensures both control and flexibility. This form of governance also meets the requirements of the cognitive level of interaction between actors by bringing together individuals who share to certain degree a cognitive frame of reference and grouping them as autonomous divisions within an organization. Thus, the organizational and the cognitive dimensions of proximity are complementary to one another.

Social proximity comprises of social relations between actors at the micro-level. Social relations are based on trust and social proximity affects the process of knowledge creation and innovation. This is because trust-based social relations facilitate the transfer of knowledge between socially proximate actors. However, too much social proximity may prompt actors to underestimate the risks of opportunistic behavior. Long-term relationships may also result in social lock-in causing actors within social networks to be resistant to new ideas and partners. A balance between both social proximity and social distance must be maintained for successful knowledge sharing and transfer. Social proximity is related to the other dimensions of proximity. Increasing social proximity may increase cognitive proximity between actors but too much social proximity may lead to an inhibition in interactive learning. Organizational proximity does not permit social proximity as it is based on hierarchical relationships. However, both organizational and social forms of proximity are characterized by strong ties although governed by different mechanisms; hierarchy and trust, respectively. Geographical proximity facilitates the development of social proximities through increased opportunities for face-to-face interactions. However, the geographical phenomenon of agglomeration also reduces the dependence on strong social ties by providing the possibility to interact with a wide range of partners and increasing the accessibility to geographically diverse networks.

Institutions can be formal, like rules and regulations and informal, like culture and habits. Institutional proximity provides a stable environment for knowledge transfer and learning to take place between actors. However, too much institutional proximity may also prove to be detrimental to these processes. This is because institutional proximity fosters interdependence between a set of institutions. These institutions have a structural position in the network of institutions. Any change due to a novelty of idea or approach causes instability in the larger institutional environment. Thus, any change is resisted within this environment resulting in a barrier to the entry of new ideas and actors. This problem can be resolved by providing a balance between institutional stability, openness and flexibility. Institutional proximity may be strongly interconnected to the other forms of proximity. Some organizational relationships are embedded in institutional settings. Hence, in certain cases, organizational proximity is dependent on institutional proximity. Social proximity may replace institutional proximity when there is a lack of strong institutions. Institutional proximity enables effective transactions between actors and manages uncertainties in the process of knowledge creation. When strong institutions are lacking, trust-based social relations come to play an important role. Social proximity can thus compensate for a lack of institutional proximity under such circumstances. Institutional proximity is related to the geographical dimension of proximity based on the type of institution. Informal institutions are more dependent on geographical proximity than formal institutions. This is because informal institutions tend to be more geographically localized whereas formal institutions operate across regional and national boundaries.

In this paper, geographical proximity has been defined in terms of spatial or physical distance between actors. The collocation of actors involved in knowledge intensive activities like collaboration and innovation facilitates interaction and cooperation. But this is not possible without cognitive proximity between actors. Thus, cognitive proximity combined with geographical proximity enables transfer and sharing of complementary knowledge. However, excessive geographical proximity is detrimental for knowledge production and innovation as actors become unresponsive to new developments and lose their innovative capacity. An important way of overcoming the problem of this spatial lock-in is to encourage non-local linkages. The geographical dimension of proximity is complementary to other forms of proximity as it helps in building and strengthening social, organizational, institutional and cognitive proximity. This paper also argues that geographical proximity can replaced by the organizational form of proximity. This is because organizational proximity can encourage the establishment of network relations even across large distances. The need for face-to-face interaction can be satisfied by collocating actors for a temporary period of time, as and when necessary.

An understanding of the relations between the different dimensions of proximity is important to isolate the effect of a single dimension of proximity on the process of knowledge creation in scientific collaboration. The present study focuses on the impact of the geographical dimension of proximity on scientific collaboration. The geographical dimension of proximity in relation to scientific collaboration is now discussed.

2.2.2 Geographical proximity and scientific collaboration

As has already been discussed, scientific collaboration can be affected by several factors like economic and socio-political factors, resource accessibility, funding, instrumentation, and proximity (Katz,1994; Sonnenwald, 2006; Fernandez, et al., 2016). Among these, the dimensions of proximity have been shown to play an important role in the process of scientific collaboration. The different dimensions of proximity affect some or all of the stages of collaboration in different ways. However, the role of the geographic dimension of proximity has been received considerable attention in the literature.

Geographical proximity is also called territorial, spatial, local or physical proximity(Knoben and Oerlemans 2006). Geographical proximity is known to affect scientific collaboration (Katz, 1993; M. A. Ynalvez, W. M. Shrum, 2011). In one of the seminal works on the impact of geographical proximity on scientific collaboration, it was found that “research co-operation decreases exponentially with the distance separating the collaborative partners” (Katz J. S., 1993). This implies that collaborating partners must remain in close territorial proximity for a successful collaboration to take place. There are several studies in the related literature which confirm the claims of this argument. However, the findings on the relationship between geographical proximity and scientific collaboration are not uniform across the literature. Other studies claim that geographical proximity is neither a necessary nor a sufficient condition for collaboration to take place (R. Boschma 2005). It is known that formal collaborations most often stem from informal interactions between scientists (Crane, 1972; Knoben and Oerlemans, 2006; Katz and Martin; 1997). Geographical proximity provides an opportunity for informal communication to take place between scientists by enabling face-to-face meetings. This facilitates the transfer of both tacit and codified knowledge, and the exchange, dissemination and cross-fertilization of ideas, fostering "intellectual companionship" among scientists (Katz & Martin, 1997;Knoben & Oerlemans, 2006). Communication between scientists also plays an important role in the maintenance of scientific collaboration (Sonnenwald, 2007). In order for a collaborative project to be successful there has to be effective communication about the visions, goals and tasks of the project during the initial stages of collaboration. The co-ordination of activities during the later stages of collaboration also depends on effective communication between collaborating partners. This in turn is greatly facilitated by geographical proximity.

There have been several studies that have investigated the impact of geographical proximity on scientific collaboration. However, a consensus on the importance of geographical "nearness" for the process of collaboration has not been achieved. While some scholars suggest that proximity in terms of distance promotes scientific collaboration, other scholars argue that geographical proximity may not be an essential condition for innovation and knowledge production. The following section discusses the findings of some empirical studies on the impact of geographical proximity on scientific collaboration.

2.2.3. Empirical studies on geographical proximity and scientific collaboration

Most of the studies on scientific collaboration have been carried out in the developed world. There are fewer studies which have investigated the impact of the geographical proximity on scientific collaboration in developing world. Nevertheless, an account of the key findings of the studies based in the developed countries is helpful in understanding how geographical proximity affects scientific collaboration. The findings supporting the claim that geographical proximity is indeed important for collaboration are listed prior to the studies with problematize this claim.

Liang and Zhu (2002) studied on “**Major factors affecting China’s inter-regional research collaboration: Regional scientific productivity and geographical proximity”**(Liang and Zhu 2002)**.** This is one of the few studies on proximity and collaboration in a developing region. Based on the measured frequency distribution of China’s inter-regional multi-authors papers, the pattern of China’s inter-regional research collaboration (IRRC) was shown. This study showed that geographical proximity was an important factor in determining the pattern of IRRC.

Costa, da Silva Pedro and de Macedo (2013) described “**Scientific collaboration in biotechnology: the case of the northeast region in Brazil**”(Costa, da Silva Pedro and de Macedo 2013). This is a more recent study in a developing country which shows the nature of collaboration in the biotechnology sector in the northeast region of Brazil. This study found that collaborations took place mostly at the intra-institutional level. At the intra-regional level, geographical proximity acted as a grouping factor in the formation of four clusters. Collaboration at the inter-regional level involved institutions with laboratory infrastructure and research tradition in biotechnology. At the international level, collaboration depended on national scientific cooperation programs.

Balland (2012) conducted research on “**Proximity and the evolution of collaboration networks: Evidence from research and development projects within the Global Navigation Satellite System (GNSS) industry”**(Balland 2012)**.** This study analyzes the role of proximity on the evolution of collaboration networks in the GNSS industry. This study found that geographical, organization and institutional proximity favour collaborations. The study states that geographical proximity and face-to-face meetings are essential for the processes of innovation and knowledge creation. Social and cognitive proximity were not found to be significant for the formation of collaboration networks.

Fernandez, Ferrandiz, Leon (2016) studied on “**Proximity dimensions and scientific collaboration among academic institutions in Europe: The closer, the better?”**(Fernandez, Ferrandiz and Leon 2016)**.** They found that while geographical proximity, cognitive proximity, institutional proximity, social proximity and economic distance played a substantial role in the shaping scientific collaboration, organizational proximity had a weaker effect on scientific collaboration.

The above findings are uniform in their conclusion that geographical proximity plays an important role in scientific collaboration both in the developed and the developing regions. However, these studies do not coincide in their conclusion about the role of the other forms of proximity in promoting collaboration. Furthermore, there are found studies in the literature which contradict the finding from the above listed studies that geographical proximity is important for scientific collaboration. The studies that follow give evidence for the finding that geographical proximity is not essential for the process of scientific collaboration.

Rallet and Torre (1999) investigated the question, "**Is geographical proximity necessary in the innovation networks in the era of global economy?**"(Rallet and Torre 1999). The paper puts to test the hypothesis that the actors of innovation need to be to in physical proximity for the transfer of tacit knowledge which requires face-to-face communication. In their research on three French regions, the authors found that non-local relations are instrumental in developing innovation. This paper ultimately suggests that policies should be oriented towards non-local relations in the same way as the local relations.

Mc Kelvey, Alm and Riccaboni (2003) addressed the following concern reflected in the title of their paper, "**Does co-location matter for formal knowledge collaboration in Swedish biotechnological-pharmaceutical sector?**"(Mc Kelvey, Alm and Riccaboni 2003). This paper addresses the validity of the assumption that co-location is important for innovation by analyzing whether co-location matters for formal knowledge collaboration in the Swedish biotechnological-pharmaceutical sector. The key finding of this study is that co-location of collaborating partners within the region and the nation is less common as would be anticipated within the systems of innovation approach. The likelihood of "close collaborations" is just as frequent as other forms of collaboration.

Moodysson and Johnsson (2007) studied "**Knowledge collaboration and Proximity: The spatial organization of biotech innovation firms"**(Moodysson and Johnsson 2007)**.** This paper investigates the role of proximity for knowledge production in eight Swedish biotechnology firms. One of the key findings of this study is the importance of global knowledge production to the Swedish biotechnology firms . Although local collaborations are convenient, the need for specialized knowledge drives the firms to look for geographically distant collaborative partners in the global level.

Crescenzi, Nathan, Rodriguez-Pose (2016) addressed the following question in their study, "**Do inventors talk to strangers? On proximity and collaborative knowledge creation**"(Crescenzi, Nathan and Rodriguez-Pose 2016). The aim of this study was to investigate the type of proximities between inventors in partnerships that lead to technological progress in the United Kingdom. This study shows that external networks are the key features of inventors in the innovation teams. The research shows that these external networks are highly dependent on previous social connections and are independent of cultural and cognitive proximities. Geographical proximity has a weak influence on these networks showing that inventors in the inventive teams rely on networks that are formed irrespective of geographical proximity. The study goes on to suggest that policies should focus on the facilitation of open and diverse networks of innovators rather than promoting spatial clustering for encouraging innovation

The findings from the studies discussed above indicate that there is considerable debate over the significance of geographical proximity in the process of scientific collaboration. The emerging literature on the geographical dimension of proximity also indicates that with the advancements in transport and communications technology, the perception of spatial distance is being redefined (Torre and Rallet, Proximity and Localization 2005). The present study attempts to understand how advancements in ICT can facilitate scientific collaboration across long distances.

2.4. Advancements in ICT and the future of scientific collaboration

In his speech, presented at the Second Berlin Workshop on Scientometrics and Informetrics in September 2000, Donald deB Beaver had said, "The expansion of the World Wide Web and the growing number of electronic journals are likely to bring changes in research practice, which will in turn be reflected in the conventions of formal "publication", whether singly or multiply-authored"(D. d. Beaver 2001).

Indeed, the literature suggests that the recent developments in ICT, like the Internet and the *electronic mail,* have changed the way in which scientists carry out their research, communicate and collaborate with one another (Walsh, Kucker, & Maloney, 2000; Walsh & Maloney, 2007). This is particularly true for collaboration across large distances. In the same speech, Beaver had said that owing to the developments in ICT, geographical diversity will increase considerably in collaborations and physical location will no longer be a barrier to research. More recent studies have also suggested that ICT may have a direct impact on remote collaboration (Sonnenwald D. H., 2007). It has been shown that although ICT that is not supported by the existing policies and practices of a location do not increase scientific collaboration (Duque, et al., 2005; Sonnenwald, 2007), it can, however, facilitate collaboration in projects which do not require scientists to be collocated (Sonnenwald D. H., 2007).

The internet technologies, particularly the *electronic mail* or *email*, have been shown to facilitate scientific collaboration (Walsh, Kucker, & Maloney, 2000; Walsh & Maloney, 2007). The use of email has been shown to be associated with fewer co-ordination problems during the duration of scientific collaboration (Walsh and Maloney 2007). The costs of communicating over long distances has also been significantly lowered with the use of email in joint scientific work (Walsh and Maloney 2007). These advantages of the internet technologies are particularly important for scientific collaboration in the resource-constrainned scientific institutions in the developing world.

In a study conducted in the developing region, interviews with scientists in Kerala, a south-western state of India, indicates the optimism and the possibility that scientists associate with internet use in scientific research (Davidson et al., 2002). Although access to the internet may not be uniform in its distribution, it has been shown in the case of South Africa that uninterrupted and uniform access to the internet can bring about a favorable increase in scientific collaborations (Sooryamoorthy, 2007; Sooryamoorthy, 2009). This implies that the possiblity of a future with ready, reliable and speedy internet connective can be successful in promoting scientific collaboration in the developing countries. These assumptions need to be verified with further empirical research in the developing region.

ICT can play an important role in the process of democratization of access to information and the creation of novel scientific knowledge(Duque, et al. 2009). The Internet has the potential to integrate peripheral scientists into the international scientific community(Shrum, Reagency of the Internet, or, How I Became a Guest for Science 2005). The present study attempts to explore the role of the internet in scientific collaboration by addressing some the important issues pertaining to internet use in scientific reseach. These include the impact of the Internet on scientific acitvites, the impact of the Internet on non-collocated collaboration, and whether internet-based means of communication is capable of replacing face-to-face collaboration. These issues are dealt with in the next chapter.

Chapter 3

Internet use and its impact on collaboration across distances

Science is a social system that is concerned with the generation of novel scientific knowledge. How scientists generate or create scientific knowledge has been a matter of immense interest in the sociological studies of science. In the past few decades, the scientific world has seen a tremendous shift in the mode of knowledge production from single-investigator research to collaborative research. As collaborative research has gained in importance over the years, studies on the collaborative mode of knowledge production have also gained in significance. The recent advances in information and communications technology (ICT), like the Internet and the electronic mail (email), have ushered in new ways of conducting, and participating in, collaborative research. In order to have a holistic understanding of the process of knowledge production in the contemporary era of ICT, it becomes imperative to study the role of the Internet in scientific research, both in the developed as well as the developing world.

In the year 2000, Donald deB Beaver had stated the implications of the expansion of the *World Wide Web* for non-collocated research(D. d. Beaver 2001). He had predicted that the advent of the *email* would ensure an increase in the diversity of geographic locations of collaborating partners, and that physical distance would no longer be an impediment to collaborative research. This is particularly important for scientists in the developing countries. The scientists in the developing region are thought to be “isolated” from their counterparts in the developed world (Dedijer, 1963; Salam, 1966; Shrum & Campion, 2000). The Internet could provide solutions to overcome this isolation by facilitating collaboration across distances(Ynalvez and Shrum 2009). There are several studies on the link between internet use and research productivity and collaboration (Barjak, 2006; Ynalvez & Shrum, 2011; Vasileiadou & Vliegenthart, 2009; Duque, Ynalvez, Sooryamoorthy, Mbatia, Dzorgbo, & Shrum, 2005). However, a majority of these studies have been conducted in the developed world with only a few studies being based in the developing world. The findings on the relationship between internet use and research productivity and collaboration differ among the studies. This relationship becomes all the more complex in the developing countries due to the contingent problems arising out of the local contexts in these countries(Duque, et al.

2005). With this context in mind, it becomes necessary to carry out closer investigations of this link. Whether the Internet has changed the very structure of the scientific community, and whether this change has enabled scientists in the developing world to be integrated into the global scientific community, are pertinent questions to the sociological study of science.

The Internet has brought about new possibilities for joint scientific work, especially in the case of geographically dispersed collaborators (Finholt, 2003; Ynalvez & Shrum, 2009). Communication, both formal and informal, is important for initiating and maintaining collaborations, especially across long distances. It has been observed that informal communication almost always precedes collaborative ventures (Sonnenwald, 2007; Crane, 1972). In the case of *non-collocated* or *remote* or *dispersed collaboration*, there is limited opportunity for scientists to meet in person and have informal discussions about their work. Hence, the Internet has a very important role to play in mediating interaction among geographically dispersed scientists.

The use of the *electronic mail* or *email* is important to research activities. This channel of communication has been shown to be more widely utilized in conducting scientific research in the developing world than the other internet-based means of communication like *videoconferencing* and *chat* (Ynalvez & Shrum, 2009; Ynalvez & Shrum, 2011). Scientists collaborating across distances now have an additional medium of connectivity through the Internet. It has been shown that although Internet use has facilitated the process of collaboration, it has not been able to replace *face-to-face communication* between collaborative partners (Barjak, 2006; Vasileiadou & Vliegenthart, 2009). Meetings between the collaborative partners are considered essential and irreplaceable for the process of collaboration. This finding, again, is an outcome of studies conducted in the developed world and whether or not it holds true in the developing regions, in this case the north-eastern region of India, is one of the primary concerns of the present study.

In the previous chapter, the literature on the impact of geographical proximity on scientific collaboration has been discussed extensively. It has been argued by some authors that geographical proximity is essential for joint scientific work. Collaborators mostly tend to select partners from the same spatial location (Balland 2012)**.** However, this argument does not take into account instances of remote collaborations. Remote collaboration, i.e., collaboration between units separated by large distances, has the potential to break the “isolation” of scientists in the developing region by allowing peripheral scientists to participate in the production of new scientific knowledge. However, collaboration across large distances face problems of co-ordination and co-operattoin due to the difficulty of communication across large distances. Computer-mediated communication can facilitate remote collaboration to a large extent but cannot completely replace the need for face-to-face communication. The concept of temporary geographical proximity (TGP) coupled with the communication through internet technologies can provide a solution for the challenges faced in collaboration across distances.

3.1. Pre-ICT era: social organization and communication in science

In her book published in the year 1972, Diana Crane, building upon the work of Price, demonstrates that the growth of scientific literature and hence, scientific disciplines follows a logistic curve (Crane, 1972; Price, 1963). This curve comprises of a period of exponential growth which implies that the growth of scientific knowledge is cumulative and hence, builds upon prior work accomplished in a research area. In her book, Crane argues that this period of cumulative growth of scientific knowledge is a result of the existence of a social organization within scientific disciplines that influences the growth of a field.

Social interaction among scientists plays an important role in the growth of scientific knowledge. That this growth follows a logistic curve comprising of a period of exponential growth indicates that scientists build upon each other's work and hence, adopt innovations made by their predecessors(Crane 1972). This implies that ideas are transmitted from person to person. There is kind of a diffusion process through which ideas and innovations are transmitted between individuals. This diffusion occurs through a social influence process in which the early adopters of an innovation or an idea influence other scientists who have not yet adopted it. The probability that an innovation will be adopted by the other members of a research area increases with time as it is proportional to the number of people who have already adopted it. Thus, the exponential growth of scientific knowledge can be defined in terms of a "contagion" process, in which early adopters of an innovation or an idea influence the later adopters resulting in the exponential increase in the number of publications in an area and the number of new members entering it(Crane 1972). In research areas where the members are not in communication with one another and with authors who have not published in the area, the growth rate is linear as the probability of an innovation being adopted by later adopters remains constant(Crane 1972). This suggests that the growth of a research area depends on both cognitive and social events and the interaction between them(Crane 1972).

Communication between scientists mediates the social influence process or the "contagion" effect that brings about the dissemination of ideas and innovations. This effect is a result of the influence of a few highly productive and highly visible "core" scientists who transmit information *informally* across an entire research field(Crane 1972). This small set of "core" scientists within a research area forms a *communication network* or an *"invisible college"* that links scientists within an area, either directly or indirectly(Crane 1972). These core scientists yield considerable influence over the cognitive growth of a research area by establishing operational paradigms within the area and are instrumental in recruiting new members as well as maintaining the growth of the research field. This shows that scientific research areas are organized into a central "core" of elite scientists responsible for the transmission of ideas through personal influence within the research field.

According to Crane, the most important indicators of social organization within a research area are the types of ties or relationships between the scientists in the area. These ties include informal discussions of research, published collaboration, relationships with teachers and the influence of colleagues upon the selection of research problems and techniques(Crane 1972). If social organization exists in a research area, the members of the research area must be linked to one another through at least one of these ties. Indirect ties, where two scientists never actually meet but are connected to each other through correspondence or publications, or through one or more intermediary scientists, are also important indicators of social organization in a research area(Crane 1972).

The four types of direct ties or relationships reinstate the importantce of communication in scientific research. There are two forms of communication that can occur in scientific research – *formal communication* and *informal communication.* Formal communication includes formal interaction and correspondence between scientists during the course of research activities. This also includes publication of research findings in publication outlets, conferences and meetings. Informal communication involves sharing and exchanging of ideas in a casual, informal environment through informal interactions (Crane, 1972; Sonnenwald, 2007). Informal communication is also known to give rise to collaborations.

In the case of *non-collocated* collaboration, it is this informal interaction arising from *face-to-face communication* that proves to be a limiting factor. In initiating and maintaining geographically dispersed collaborations, scientists have to overcome additional challenges in specifying and communicating research goals and tasks, co-ordination of research activities and resolving of disagreements that are most likely to develop during the course of the project(Sonnenwald 2007). It is yet to be seen whether the advent of the Internet and the development of novel channels of communication have contributed to the mitigation of these challenges.

3.2. The changing form of scientific organization

The historical form of organization in science is characterized by the presence of *"invisible colleges"* within scientific research areas. These *"invisible colleges"* comprise of a few highly productive and hence, highly visible members who make up a "core" of scientists. These scientists establish the operating paradigm within a research area by influencing the selection of the set of fundamental problems for research(Crane 1972). This influence is yielded through informal communication with other scientists, both within and without the research area, resulting in the dissemination of information across the field(Crane 1972). This dissemination of information through informal communication between leading scientists is important in ensuring the cumulative growth of scientific knowledge.

Apart from influencing the communication of information within a research area, social organization in science also influences the publication productivity of scientists. In the traditional form of scientific organization, the "core" scientists are the most productive members in the research area and are responsible for a high proportion of the published output in the field(Crane 1972). This corresponds to the Lotka distribution of productivity. Thus, in the historical organization of science, research productivity of scientists is mainly concentrated within the *"invisible colleges"* with the bulk of new scientific knowledge created by a few "core" scientists working amongst themselves (Crane, 1972; Finholt, 2003). These "core" scientists may be termed as the "elite" scientists who work in state-of-the-art laboratories, preferably in the developed world and set the standards for research in a research area.

The historical organization of science can be considered to be exclusive to the extent that it fails to fully integrate scientists from the developing world into the global scientific network. The problem of the “isolation” of scientists in the developing world was first highlighted by Stevan Dedijer in the year, 1963(Dedijer 1963). In his paper, Dedijer draws a comparison between the status of science in the developing world as opposed to the developed world, back then. Among the many problems which afflicted the progress of scientific research in the less developed economies, he stated the problem of the “isolation” of developing countries scientists as being of primary concern. At the time when Dedijer wrote this paper, the developing countries were yet to form fully established scientific communities and hence, the scientists in these countries were geographically dispersed and disconnected from one another. They were also isolated from the pioneers of research in their respective fields in the more advanced developed world and this directly affected the quality of their work. Three years later, Abdus Salam, a theoretical Physicist, after completing his education from Cambridge and Princeton and upon returning to Pakistan, found himself ‘desperately isolated’ in his native country (Shrum, 2005). His experiences led him to articulate on the problem of the isolation of developing countries scientists(Salam 1966).

It is taken for granted that science is a “communal” and a “collective” activity and that the structure and the process of communication is pivotal for the generation of new knowledge (Crane, 1972; Glaser, 2003). However, in the sociological accounts of science, the context of the developing world is under-represented (Shrum, 2005). That scientists in the developing world suffer from “isolation” from each other and from the international scientfic community, even today, is evident from an analysis of their professional networks. The notion of isolation has two forms: the *empirical form* and the *normative form* (Dedijer, 1963; Shrum & Campion, 2000). The *empirical form* implies that the developing countries scientists have very few professional contacts. The *normative form* implies that the developing countries scientists should have greater contats with their counterparts in the developed world. The studies on the professional networks of scientists have addressed only the normative aspect of the notion of isolation. These studies show that scientists in the developing world have greater contacts within their national research systems (Shrum & Campion, 2000) and that they favor either local or domestic ties (Shrum & Campion, 2000; Ynalvez & Shrum, 2009; Duque et. al, 2009).

In relation to both the above findings, the Internet has an important role to play. The Internet is expected to solve the problem of the “isolation” of developing countries scientists as well as resolve the inverse realtionship between domestic and foreign ties. This relies heavily on the information and communications technology in overcoming the challenges arising from spatial as well as temporal constraints. The channels of communication provided by the Internet, like the *email*, *chat* and *videoconference*, as well as its information storage and retrieval technologies can, to a large extent, bridge the gap between scientists in the developing and the developed world. This integration of the developing countries scientists into the global scientific network would lead to a "dramatic revision" of the historical organization of science away from the *"invisible colleges"*(Finholt, Collaboratories as a new form of scientific organization 2003), leading to a larger proportion of scientists participating in the generation of novel scientific knowledge as opposed to the concentration of the productive scientific workforce within the *"invisible colleges"*.

The change in the social organization of science to include peripheral scientists through Internet technologies enables an increase in the participation of these scientists in cutting edge research. This gives rise to a redistribution of the share of intellectual contribution to the generation of novel scientific knolwedge. The growth of a scientific research area involves both cognitive as well as social processes(Crane 1972). In the reorganization of scientific areas, social processes within scientific fields can lead to cognitive changes within the field. This phenomenon can be best descriped by the notion of "distributed intelligence"(Zare 1997) in which knowledge is available to anyone across time and space, and where "power, information and control is moving from centralized systems to individuals". Distributed intelligence ensures that knowledge and experience held by scientists can be communicated across the barriers of time and space ensuring the integration of non-elite scientists in the knowledge generation network of the world.

3.3. The Internet and the new forms of communication

The new developments in information and communications technology (ICT) have become the medium for collaboration across long distances(Ynalvez and Shrum 2011). In her article, *Scientific Collaboration*, Sonnenwald has emphasized on the importance of ICT in facilitating collaborative research, especially in the case of *non-collocated* or *remote* or *distributed* collaborations(Sonnenwald 2007). The tools of ICT can be applied to mediate scientific research across institutions, organizations and countries. These tools include *e-mail, instant messaging/chat, listservs, video-conferencing, voice over IP (VOIP), Wikis, blogs* and *other types of Web pages, shared applications* (e.g., to support synchronous data analysis), *electronic lab notebooks, shared remote access to instrumentation, shared electronic whiteboards* (e.g., used during videoconferences to support information sharing and knowledge construction), *project management tools, scheduling calendar tools* to arrange experiments in labs as well as meetings, *manuscript submission, and review systems*; and *digital libraries* and *shared data repositories*, including *thesauri, metadata,* and *information retrieval tools*(Sonnenwald 2007).

The applications of ICT utilized in research and development (R&D) can be broadly classified into three categories(Barjak 2006):

1. **Communication through computer-mediated communication (CMC)**:
   This includes the use of computer-based communication media for R&D. The channels of communication comprise of *email, chat* and *video conference.* Besides online communication media, certain offline communication media are also included.

2. **Internet-based search and retrieval of information**:
   This includes different on-line sources of information like *internet sites of libraries and archives, e-journals, full-text databases, peers' websites,* and *websites of other institutions.*

3. **Dissemination of the results of R&D through the *World Wide Web***:
   This medium of communication is based on the kind of information on themselves that the scientists choose to make publicly available through the internet. This includes personal homepages and the content of information (full text papers or hyperlinks to them) made available in these homepages.

As mentioned above, in envisioning, initiating and maintaining of a collaborative project, communication plays a pivotal role. It has been found that collaboration often emerges from, and is perpetuated through, social networks of scientists(Sonnenwald 2007). Both formal and informal communications form the bedrock of social networks between scientists. For the scope of this study, in analyzing the patterns of collaborative practices of scientists in the north-eastern region of India, it is imperative to explore the ways in which scientists located in this region communicate with other scientists. The main emphasis is to investigate whether the geographical barrier of distance has, to a certain degree, been overcome with the advent of internet based means of communication. The focus of this chapter is on on-line channels of communication which comprise of the *email*, *chat* and *video-conferencing,* and to investigate which of the three channels of on-line communication is preferred by the Entomologists in the north-eastern region of the country in conducting collaborative research.

In utilizing the internet based means of communication, scientists in this region have a possibility of being more connected to their colleagues in the national as well as the international research systems. Scientists in the north-eastern region of India can be considered to be peripheral owing to the relative geographical separation of the region from the rest of the country. Another dimension of the periphery is the institutional infrastructure of the region. In the previous chapter, the important universities, institutions and government laboratories in the region involved in biological research have been have been listed out. These are institutions are not “elite” institutions in terms of the ranking and national repute. However, some scientists in these non-elite institutions are conducting important and ground-breaking research despite their peripheral condition. How the use of the internet has facilitated in the process of knowledge production and collaboration in the north-eastern region of India will give an idea of the impact of internet technologies on science in the periphery.

3.4. Internet and its use for scientific collaboration

The idea that the Internet could be used for promoting science in the developing world is fairly recent (Shrum, 2005). That the use of internet technologies can bring about a revision of the historical organization of science, away from the *“invisible colleges”* and towards “distributed intelligence”, is promising for the integration of peripheral scientists into the international scientific community. However, scholars like Jochen Glaser, argue that the Internet does not indeed change the social order of scientific communities but only affects the communalization of raw data anaysis, the way that data is produced and the ability of non-scientists to contribute to scientific knowledge creation by providing remote access to research equipments “outside science”(Glaser 2003). This argument focusses on accounts of internet use in research activities only in the developed countries and hence, fails to take into consideration the context of the developing countries. The integration of scientists from developing countries does not "rise to the level of consciousness or discourse" (Shrum, 2005).

Studies in the developed world suggest that there is a positive impact of internet use on research productivity and collaboration (Walsh et al., 2000; Barjak, 2006; Vasileiadou & Vliegenthart, 2009). Internet use improves research productivity by providing access to information and facilitating the exchange of ideas as well as the sharing files and databases (Barjak, 2006). In terms of scientific collaboration, especially involving distributed teams, internet based means of communication is becoming important for all the stages of the collaborative process: decision-making, task allocation, co-ordination and the sharing of resources(Heimeriks and Vasileiadou 2008). In comparison to "single-investigator-research", collaborative research also entails certain additional challenges (Sonnenwald 2007). These challenges include communication of research goals and objectives, allocation of tasks, coordination of research activities, sharing of resources, overcoming disagreements and misunderstandings and the coherent interpretation of research results (Sonnenwald, 2007). Communication between the collaborative partners is important for overcoming these challenges. However, in the case of *non-collocated* collaborations, effective communication between partners, especially informal communication, becomes a limiting factor.

The literature on the impact of internet use in scientific research in the developed world is uniform in the conclusion that although internet use has brought about changes in the communication practices of scientists, it does not substitute for *face-to-face* communication (Walsh & Bayma, 1996; Olson & Olson, 2000; Vasileiadou & Vliegenthart, 2009). One of the studies found that the amount of *face-to-face* communication is the most important indicator of productivity (Vasileiadou & Vliegenthart, 2009). This study also reported that the link between *email* communication and productivity was not found to be very important. These findings appear to suggest that collocation of scientists is still an important factor in the production of scientific knowledge. This conclusion that the physical proximity of scientists is an important factor in the process of collaborative knowledge production contradicts the expectation that the Internet could provide ways of overcoming the constraints posed by physical separation.

The studies cited above are based in the developed countries and their findings are not inclusive of the meaning of the Internet in the context of developing regions. In the developing countries, communication through the Internet is an opportunity for scientists to maintain professional contacts with their colleagues in the scientifically advanced global north, even after the termination of a collaborative venture. It has been shown that *email* use is associated with an increased proportion of contacts in the developed world (Shrum & Campion, 2000; Duque et al., 2009; Ynalvez & Shrum, 2011). It is known that the number of colleagues that a scientist communicates with on a regular basis is related to the degree of collaborative activity that a she undertakes(Meadows 1974). Having contacts in the developed world also provides greater access to a variety of resources and opportunities(Ynalvez and Shrum 2011). In has also been found that in the case of resource constrained institutions, most scientists undertake collaborative projects despite difficulties in co-ordination and without any significant advantage in terms of publication productivity(Ynalvez and Shrum 2011). These findings indicate that in developing regions, collaborative research has connotations different from the developed world. Whereas in the developing countries, collaboration could be an opportunity to end intellectual isolation or acquire access to limited resources, in the developing regions, the motivation for scientists to collaborate may be certain extrinsic rewards(Ynalvez and Shrum 2011). These extrinsic motivations include travel opportunities, supplememtary income and recognition among peers(Ynalvez and Shrum 2011).

Scientists across the world are increasingly adopting the Internet for research activites. The context of this adoption differs between developed and developing regions. In the developed world, internet based means of communication are an additional facility, besides regular *face-to-face* communication through meetings, conferences and workshops. For developing countries scientists, the cost of maintaining regular *face-to-face* contact with their counterparts in the global north may exceed the benefits of collaboration (Duque et al., 2005; Ynalvez & Shrum, 2011). The internet based communication media could provide a way to overcome this problem and end the isolation of the scientists in the developing regions. It is in this context that the importance of the use of the Internet by developing world scientists must be viewed.

3.5. Computer-mediated-communication and the connectivity initiative

The notion that the Internet can be utilized in the promotion of science and technology in the developing regions found its way into discourses on development only in the mid 90s

(Shrum, 2005). In the year 1995, the United Nations Commission on Science and Technology for Development began reviewing ICT policies in Africa, Latin America and Asia and the same year the International Council for Science formed a Committee for Capacity Building in Science (Shrum, 2005). It was around this time that the problem of the "isolation" of scientists in the developing world re-emerged as a principal issue in science policy for development (Shrum, 2005). It was felt that in order for science and technology to flourish in the developing world, the problem of connection to informal and formal communication structures of science must be solved.

It was with this objective that electronic communication networks such as the Internet were established in developing regions like Africa(De Roy 1997). In Africa, the Internet was not only viewed as a tool for the promotion of science but also as a development initiative. In the context of scientific development, the Internet was shown to promote the integration of African scientists into the global scientific network(De Roy 1997). However, the diffusion of technology is dependent on several factors which include socio-economic, political and cultural factors. There appears to be a difference in the rate of the adoption of Internet technologies across countries. Although, in terms of development, the south Indian state of Kerala is relatively ahead of African countries like Ghana and Kenya, with more ready access to the Internet, the nature of its use for promoting scientific activities differs among the locations (Duque et al., 2005). It is found that scientists in Kerala have lesser international collaborations than their African colleagues despite having better access to the Internet (Duque et al., 2005). This can be explained in terms of the development of the national research systems in these countries (Duque et al., 2005). The research system of India is more developed allowing for scientists to conduct most of their research within the country. Collaborations are more domestic in nature than international.

The case of South Africa offers a unique example. The country has one of the most "developed" scientific communities in the African continent and studies conducted in South Africa show that there is a positive relationship between internet use and collaboration for South African scientists (R. Sooryamoorthy, Does the Internet Promote Scientific Collaboration and Productvity? Evidence from the Scientific Community in South Africa 2007). Another study shows that scientists in South Africa are becoming increasingly collaborative and this trend has been on a steady rise (Sooryamoorthy, 2009). The same study also shows that South African scientists prefer international collaborations over domestic collaborations. These results contradict the earlier findings based in the developed countries stating that internet use is not related to an increase in collaboration. This illuminates the difference in the process of collaboration in the developed as well as the developing countries. However, it must be borne in mind that the context of South Africa is different from the rest of the developing world. It has uniform accessibility to the Internet, a condition that is still not prevalent in many of the other developing regions (Sooryamoorthy, 2007).

There are three general perspectives on the role of the Internet in the developing areas: the "elixir" argument, the "affliction" argument and the "teething" argument (Davidson et al., 2002). The "elixir" argument states that the Internet is an opportunity for the developing world and that internet connectivity and increased bandwidth are tools that will assist in the development of the global south. Through the use of the internet technologies, scientists from the developing world can be brought out of their isolation and hence, can partake in the creation of novel scientific knowledge. The "afflication" argument views internet technolgies as a medium through which inequalities at the global level are perpetuated through technological gaps between the rich and the poor, the urban and the rural, and the English and the non-English speakers. These gaps are based on inequalities arising from access to internet technologies and the skill to utilize its benefits. The "teething" argument lies in between the "elixir" and the "affliction" argument and states that altough there will be some initial hurdles in the diffusion and adoption of the internet in the developing regions, these problems are short term and will eventually be overcome, accruing a net benefit for the developing world.

These arguments were made at times when the phenomenon of the internet was fairly new and its diffusion was too limited to have a clear idea of its impact on science. In today's global era of ICT, there is a need to view the Internet as a tool in facilitating scientific research and to investigate its intended benefit for the developing world(Ehikhamenor 2003). The emergence of the collaboratory concept finds a place of reference in the discourse on the new ways of conducting scientific investigations. Collaboratories are "laboratories without walls" where scientists are "connected to each other, to instruments, and to data" across time and distances(Finholt, Collaboratories as a new form of scientific organization 2003). Collaboratories are the new age laboratories where internet creates new possibilities for joint scientific work, especially across large distances. The emergence of a workspace which can transcend the barriers of time and space using the tools of the internet is a form of the democratization of science by including peripheral scientists in the research process.

However, owing to the nature of the innovations in ICT, there are certain structural impediments that need to be surmounted before internet proves to be the "elixir" for the developing world.

3.6. Challenges to the connectivity initiative

The connectivity initiative was expected to end the isolation of scientists in the developing world by facilitating communication between scientists of developed and developing countries. This problem has re-emerged with the advent of the Internet. To explain this problem Shrum (2005) introduced the concept of the "reagency" which is "a process of redirection involving contingent reaction between identities". The identities described in the paper are that of the "Host" and the "Guest". The Host is an identity based in a "resource constrained" developing country whereas the Guest is a "resource rich" visiting-scientist or personnel from the developed world. The role of the Guest is to redirect new initiatives, like new research projects or funding schemes, into the host country leading to the development of its scientific research system. Although the Guest brings important initiatives into the host country, she has no control over the processes that follow as a result of the introduction of these initiatives. These are largely dependent on several contingent factors that arise out of local contexts. The initiatives are designed in the global north and hence, are unable to account for the local challenges that might arise and cannot predict the nature of the interactions between identities which are in turn shaped by the place in which they are embedded. It is the interaction between these identities that determines the course and the outcome of an initiative.

However, the connectivity initiative involving the internet technologies is the sole initiative that can detach an identity from the embedded context of its place thereby, decreasing the dependence of the Host on the Guest. This detachment is achieved in the virtual world where constraints of time and space are diminished. The connectivity initiative can be realized through the internet technologies by developing and maintaining interactions with the developed world across time and space. However, Shrum also adds that although the connectivity initiative can be successfully implemented in the host country, continued personal and face-to-face communication is necessary for ensuring the proper utilization of the Internet. This argument suggests that the connectivity initiative in the developing regions is not sufficient in itself, and requires “guidance” in the form face-to-face communication from scientists from the advanced countries in order to be beneficial.

Another argument against the advantages of the internet in promoting science and scientific collaboration in the developing world is the collaboration paradox. While pointing out the limitation of Internet, some scholars suggested the problem of the “collaboration paradox”: the conditions that unsettle the relationship between collaboration and productivity in developing areas that may undermine the collaborative benefits of new information and communications technologies (Duque et al., 2005).They argue that the problems of collaboration arise out of the local context of the developing countries and there is not much difference in the degree of problems faced by the scientists who take part in collaboration and scientists who do not. These problems can undermine the benefits of the internet for collaborative processes, including in the developed world. This paradox problematizes the connectivity initiative for the promoting scientific activity in the developing world.

Another major impediment in the success of the connectivity initiative in the different parts of the developing region is the non-uniformity of internet access across these areas. The problem of access must be viewed not as the “digital divide” which poses a dichotomous measure of access between “haves” and “have-nots” but as “digital inequality” (DiMaggio and Hargittai 2001). Digital inequality takes into account not just access to the internet but also inequality among persons with formal access to the internet. One such aspect of inequality is the inequality of access to the inequality of hardware, software and connections. Internet use also depends on social, demographic and psychological factors (Lenhart and Horrigan 2003). These inequalities in the access to and the use of the Internet are characteristic of the regions in the developing countries (Davidson et al., 2002; Duque et al., 2005; Shrum, 2005). The problem of digital inequality poses a significant challenge to the success of the connectivity initiative.

With the increase in the diversity of the use of the Internet, there is also a possiblity of the balkanization of science. Balkanization in science has the potential to generate new forms of exclusions through the use of internet technologies (Alstyne and Brynjolffson 1996).Where the internet can reduce the physical barrier between geographically dispersed scientists, it may also cause selective association between scientists. These selections may be based on similarity in specialty, position or politics. The Internet may lead to the integration of scientists from remote geographic spaces, however, it is yet to be seen which scientists are going to be included in the professional networks of developed countries scientists. Thus, internet technology can lead away from “geographic balkanization” into “electronic balkanization”. It is one of the primary focuses of the present study to investigate whether the scientists from the peripheral north-eastern region of India share the view that the Internet facilitates collaborative research across distances.

3.7. Temporary geographical proximity (TGP), ICT and scientific collaboration

In some of the studies on scientific collaboration, it has been claimed that geographical proximity encourages scientific collaboration. This assumption is supported by the view that face-to-face communication is an indispensable part of the process of knowledge production. The importance of face-to-face communication for scientific collaboration is based on the necessity of the transmission of tacit knowledge between partners. However, the transfer of tacit knowledge does not imply permanent conditions of physical collocation of collaborating partners throughout the duration of the collaborative project. This section of the essay introduces the concept of temporary geographical proximity (TGP) and discusses how TGP combined with computer-mediated communication can overcome the barriers of physical distance for collaborations across long distances.

In the literature, knowledge has been classified into two types- tacit and codified knowledge (Polanyi 1966). Tacit knowledge is the form of knowledge that cannot be easily transferred between individuals as it cannot be reduced to an explicit form (Rallet and Torre 1999). Codified knowledge, on the other hand, can be converted to messages that can be transferred between actors (Rallet and Torre 1999). Scientific knowledge comprises of both the tacit and the codified dimensions of knowledge. The communication and the exchange of these two forms of knowledge has important implications for the process of knowledge production as well as scientific collaboration.

Codified knowledge does not always require communicators to be physically proximate and can be transmitted across time and space using the advancements in communications technology like electronic mail, videoconfercing (Rallet and Torre 1999). However, as tacit knowledge cannot be converted to an explicit form it requires face-to-face communication between the communicators in order to transmit knowledge by sharing practical work experiences and learning work cultures (Rallet and Torre 1999). As a result, geographical proximity appears to be an necessary condition for the efficient tranfer of information in knowledge intensive activities like scientific research (Rallet and Torre 1999). Indeed, it has been shown that knowledge charaterized by the tacit component is most sensitive to the physical dimension of proximity (Moodysson & Johnsson, 2007). However, the transfer of tacit knowledge in the process of scientific collaboration does not require actors to be collocated throughout the duration of the project.

Geographical proximity is a doubly relative concept (Rallet and Torre 1999). First, it is relative to the means of transport. The spatial distance is estimated in terms of time and the cost of travel. Second, it is not just an objective data but is also based on the judgement of individuals about the subjective interpretation of the factors which influence distance. This concept of geographical proximity is linked to the concept of “mobility” found extensively in the literature on proximity. Mobility of individuals enables them to act at different places in closely separated moments of time(Torre and Rallet, Proximity and Localization 2005). With the advancements in transportation and communications technologies, the time costs and the economic costs of travelling have decreased significantly, greatly increasing the mobility of individuals. These advancements have helped to ‘shorten distances’ thereby, changing the way in which geographical distance is perceived.

The increased mobility of individuals due to advancements in transportation infrastructure and technologies has indeed made permanent geographical proximity between actors redundant. Geographical proximity affects only certain phases of interaction between actors. These include the following phases-for the negotiation of the terms of the transaction between actors, the defining of the guidelines and the organizational framework under which actors choose to co-operate, for sharing of research equipments and instrumentation during the experimental phase of a collaborative project, for exchanging knowledge, and most importantly, for getting to know personally the members within a scientific community (Torre & Rallet, 2005). The information needed for co-operation can thus be exchanged during temporary face-to-face meetings. The need for actors to be permanently collocated is therefore not necessary.

Temporary geographical proximity (TGP) is a form of geographical proximity that enables temporary face-to-face interaction between actors, who may be individuals or organizations or geographical locations (Rallet & Torre, 1999; Torre & Rallet, 2005; Torre A., 2011). It has already been discussed that the developments in ICT, particularly the advancements in communications technology facilitate long distance collaboration and reduce the dependence of collaboration on geographical proximity. However, the need for face-to-face interactions cannot be underestimated through the use of these technologies (Torre & Rallet, 2005; Torre A., 2011).

Based on the requirements of communication between actors collaborating across large distances, a study has described long-distance collaboration in terms of the following three stages- initiation, long-distance teamwork and the stage of temporary face-to-face communication (Torre A. , 2011). During the initial stage, the members of a collaborative team are collocated for a specific duration of time. This duration depends on the nature and the complexity of the project. During this stage of co-presence, get to know one another, build a common knowledge base, discuss the technical details of the project and plan the future stages of the project. This is followed by a period of long-distance teamwork interspersed by periods of occasional face-to-face meetings. The phase of long-distance teamwork involves the use of communications technology for the co-ordination of research activities across geographical distances. The phase of occasional face-to-face meetings comprises of instances of temporary geographical proximity (TGP). Thus, this study, by introducing the concept of TGP and by coupling TGP with long-distance teamwork supported by ICT, provides a solution to the problems of scientific collaborations across distances. Thus, a balance between face-to-face relations and computer-mediated communication is achieved through the mobilization of TGP.

The concept of TGP is of special significance to collaborative activities in the north-eastern region of India. This region lies at the periphery of the country and the present study aims to investigate whether the constraints of geographical distance have an impact on the collaborative patterns of scientists located in the region. The next chapter provides a broad outline of the region with an aim to describe the geographical context in which the study is based. The choice of the scientific discipline in which the patterns of collaboration is studied has also been discussed in the following chapter.

Chapter 4

Entomology research in North-east India

The north-eastern region of India comprises of eight of the twenty nine states in the country. This includes Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. This region lies at the north-east frontier of India bordered by China, Nepal and Bhutan to the north, and Bangladesh and Myanmar to the south. The north-eastern region is connected to the eastern region of the country through a narrow strip of land tightly flanked by Bhutan and Bangladesh. This narrow corridor of land is called the Siliguri corridor and is a part of the eastern state of West Bengal. Its width lies between 21 to 40 kilometres. The Siliguri corridor is the only geographical link that the north-eastern region has with the rest of India.

Historically, the region comprises of the Seven Sisters States (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura) and the lower Himalayan state of Sikkim. The geographical area that now makes up the Seven Sisters States became a part of the Republic of India only in the 19^{th} century. The state of Sikkim was annexed to India in the year 1975 and became a part of the north-east region later, in the 1990s. The political situation in the region remains volatile owing to political unrest and this has had an immediate impact on the socio-economic development of the region.

Scientific collaboration is a mode of knowledge production that is embedded in the larger social context of science (Sonnenwald 2007). This larger context gives rise to certain factors that arise out of the social, economic and political conditions of a region and have a direct impact on the process of scientific collaboration(Sonnenwald 2007). This chapter discusses the social and the geographical context of the north-east region in order to understand how certain factors affects the production of scientific knowledge in the region. The degree of scientific collaboration has also been shown to vary across scientific disciplines (Newman, 2004; Fernandez, Ferrandiz, & Leon, 2016). This suggests that the study of scientific collaboration within the framework of a single research area gives a more precise understanding of the factors that affect the degree and the patterns of collaboration within the discipline. The present study measures collaboration among scientists in the field of entomology. The chapter also discusses the choice of the scientific discipline for the present study and gives a brief outline of the nature of this discipline. Studies on Indian science have also been discussed to place entomological research in the north-eastern region within the larger context of Indian science. The aim is to illuminate the conditions under which scientific knowledge is produced in the field of Entomology in the peripheral region of a developing country.

4.1. The region of North-East India

The area of the north-east region is approximately two hundred and sixty two thousand square kilometres (~262,000 km^2), about eight percent (8%) of the total size of India. Its population, according to the 2011 Census report, is about forty six million (~46,000,000), roughly around three percent (3%) of the total population in India. The gender ration is slightly better than the national average with about 954 females per 1000 males as opposed to the national ratio of 940 females per 1000 males.

Although this region is replete with natural resources and houses a huge pool of human capital, in terms of economic development it lags behind some of the more developed states in the country. It is listed under the bio-diversity hotspots of the Indo- Myanmar region. The economy of the region is largely based on agriculture with about seventy percent (70%) of the population depending on it for their livelihoods(India's North-East: Diversifying Growth Opportunities 2013). The region has a forest cover of more than sixty-six percent (66%), ranging from about thirty-five percent (35%) in Assam to approximately, ninety-seven percent (97%) in Mizoram(India's North-East: Diversifying Growth Opportunities 2013). Despite these figures, the region continues to be a major importer of food crops for its own consumption due to the limited area of land available for agricultural activities(India's North-East: Diversifying Growth Opportunities 2013).

The above mentioned conditions indicate that there is considerable potential for sustainable development in the region to bring about economic growth and development. Research and development in science and technology can greatly contribute to bring about these changes. The unique conditions in the north-east region make scientific research of increasing relevance for the economic growth and development of the region.

4.2. An overview of Indian Science

The development of infrastructure for science and technology in India began around the time of independence with the setting up of universities, national laboratories and autonomous research institutions(Kumar, Garg and Dutt 2009). India has since developed a large scientific infrastructure and has been consistently contributing to the overall global growth of scientific knowledge, albeit at a lower rate than the developed countries. Research publication is an important output of science and is representative of a country's scientific activity(Bhattacharya, Shilpa and Kaul 2015). The past few decades have seen an increase in India's global share of publication output, along with other emerging economies(Bhattacharya, Shilpa and Kaul 2015). This section gives a broad overview of Indian scientific research and its share in the global production of scientific knowledge in order to elucidate the context of the present study.

There is a long history of the use of scientific literature for analyzing scientific activity(Garg 2003).The peer-review system involving expert decision processes by well-informed and experienced peers is a standard method of reviewing scientific literature. In addition to this system, bibliometric analysis is used to carry out quantitative evaluation of scientific literature in terms of publication productivity, citation counts and citation impact. This methodology is based on bibliometric data derived from publications and citations. Bibliometric analysis is utilized to estimate the total as well as, discipline-wise research output of a country within a given time-period.

Over the years, bibliometric assessment of Indian Science has been carried out in several studies (Kumar, Garg, & Dutt, 2009; Anuradha & Urs, 2007; Gupta & Dhawan, 2009; Bhattacharya, Shilpa, & Kaul, 2015). A part of bibliometric analysis is to estimate publication productivity in different scientific disciplines across institutions, sectors and nations. The findings of some of these studies are discussed below.

A study conducted by Dhawan and Gupta in the year 2009 provides a number of indicators on science and technology (S&T) in India in order to estimate the country's progress in research and development. The study utilizes publication data from the Scopus international database for India and 20 other countries for the period 1996 to 2006 to draw a comparative analysis on several measures of scientific activity. Some of the important findings relevant for the present are discussed in this section. In the period analyzed, the national share of publication productivity in the subjects in the Life Sciences subjects was 30.2% of the total national output. This is the second highest share of publications coming next only to the physical sciences (41.2%). Agricultural and biological sciences are among the high productivity subject areas of research. In terms of the geographical distribution of India's scientific output in terms of publications, Tamil Nadu, Maharashtra, Delhi, Karnataka, West Bengal, Uttar Pradesh and Andhra Pradesh are the most highly productive states. The states of the north-eastern region come under the category of low productivity states in terms of publications in science and technology (S&T). None of the science and technology institutions are included in the group of most productive S&T institutions in the country.

In a recent report published in the year **2015** by **Thomson Reuters** in collaboration with the **Department of Science and Technology**, **India**, the total scientific output of India for the period of 2005-2014 has been outlined based on the data from the online database, ***Web of Science***(India's Research Output and Collaboration (2005-14): A Bibliometric Study 2015). This report gives a comparative analysis of India's research output and citation impact. The key findings of this report are discussed as follows. India's total output of research papers, included under the broader disciplines of *Chemistry, Physics, Clinical Medicine, Engineering, Materials Science, Biology & Biochemistry, Agricultural Sciences, Plant & Animal Sciences, Pharmacology & Toxicology* and *Geosciences*, account for **3.4% of the world total research output**, compared to a selection of 19 countries. India's contribution is greater than that of the established research economies of Australia, Switzerland, the Netherlands and Sweden. This increase was seen every year between 2005 and 2014. Among the eight emerging research economies, including the BRICS countries, India ranks **third** in total research output, lagging behind only China and South Africa. China accounted for the highest share of published papers among the emerging research economies.

In the same year, another study by Bhattacharya, Shilpa and Kaul in the year elucidated the factors that have affected the publication productivity in S&T in India after the 1990s (Bhattacharya, Shilpa and Kaul 2015). The authors have shown that there is a change in the global landscape of scientific activity (Bhattacharya, Shilpa and Kaul 2015). Emerging countries like China, India, South Korea and Brazil are becoming increasingly productive in scientific research. India was the leading country among developing economies in terms of scientific publications till early 1980s.This growth of Indian scientific literature, however, experienced a sharp decline thereafter, but recovered from the year of 1995 showing an increasingly positive trend in publication productivity. This paper explores the reasons behind this publication growth after the 1990s in India. The data is obtained from Science Citation Index-Expanded and the Scopus database for the period from 1990 to 2012. The paper discusses four factors that have influenced this positive trend in publication productivity in science and technology. These are as follows. First, there has been expansion of journals in global databases and also the more Indian journals have been included in these databases. Second, the number of institutions involved in publishing has increased over the years. Third, there has been a net increase in the instances of international collaboration enhancing the visibility and impact of scientific publications. Finally, there has been an increase in the scientific activity of the country in emerging research areas like nanotechnology, biotechnology, advanced materials, computational and synthetic biology.

The present study is concerned with production of scientific knowledge through the process of collaboration. The degree and the patterns of collaboration are estimated in a particular research area in the biological sciences called Entomology. As has already been discussed, the literature suggests that there is disciplinary difference in scientific collaboration with biological sciences tending to be more collaborative in nature. The following section discusses the characteristic of the field of entomology and conditions of scientific research in the field within the north-eastern region.

4.3. Entomology as a discipline

Entomology is a scientific discipline which deals with the study of insects. Traditionally, entomology is considered to be a branch of Zoology. However, through the course of its development, it has grown into a scientific field quite distinct from its parent discipline. The focus of entomology is on insects, both beneficial and pestiferous. It is interesting to note how this discipline has developed and is still developing into a diverse body of knowledge which seeks answers to some of the most practical problems of human existence.

The discipline of entomology has its ancient origin in the efforts of humankind to harness the benefits of a select few beneficial insects, like the bee and the silkworm(Essig 1936). However, in contemporary times, entomology has metamorphosed into a discipline that encompasses a variety of sub-fields such as *insect morphology*, *insect systematics*, *biochemistry*, *genetics*, *ecology*, *toxicology*, *pest management*, *environmental entomology*, *insect pathology* among others. The advent of molecular biology tools has redefined the fundamental set of problems that are investigated under the purview of entomological research, allowing the field to explore and discover domains that were not possible as recently as twenty years ago. This has resulted into a change in the operational paradigm of this once conservative scientific research field.

In the research area entomology a "paradigm shift" was observed around the 1980s as a result of the advent of a revolutionary set of tools in the form of molecular biology tools. The molecular biology tools, like the *polymerase chain reaction* (PCR) or the *automated sequencing of DNA*, have caused a revolution in the entire discipline of biology. These are tools that have enabled a molecular biology approach, involving analysis at the molecular level of genes and proteins to the different problem-solving techniques in biology. In the time around the1980s, these tools began to find increasing relevance in the field of entomology (Pennisi, 1989; Caterino, Cho, & Sperling, 2000). Where the traditional approach focussed primarily onmodes of enquiry which derive from traditional methods and techniques in Zoology, the advent of molecular biology has broadened the horizons of entomological research. There began to emerge new areas of research within enotmology like *insect molecular systematics*, *insect genetics*, *insect biochemistry and molecular biology* which use the molecular biology tools for seeking answers to the problems in the research area.There was a gradual shift in the paradigm of the discipline giving rise to a new set of problems, altogether, arising from the new molecular level of analysis. For example, traditionally, research in Entomology included research on pesticides and insecticides for controlling pestiferous insects. The use of pesticides and insecticides entail certain environmental costs. Now, with the help of molecular biology tools, certain alternative methods like the synthesis of plant based compounds against pests are being tested to replace chemical pesticides and insecticides. These changes have led the discipline to slowly metamorphosize from *Entomology* into *Insect Science,* keeping intact the relevance of the traditional body of knowledge while accomodating new ways of doing science.

4.4. Status of Scientific Research in Entomology in India

Standard bibliometric methodology makes use of journal categories as a proxy for research areas. *Thomson Reuters* makes use of the same approach and assigns all journals to one or more subject areas which are used to classify the subject matter of the articles in the journals. These subject areas are called the *Thomson Reuters InCites: Essential Science Indicator fields*. There are 22 Essential Science Indicator fields. However, the discipline of entomology is not directly represented in these indicator fields. On the contrary, owing to the diversity and multi-disciplinary nature of contemporary research in entomology (as described in the previous section), the subject matters of journal articles relating to entomological research can be included under the following Essential Science Indicator fields- *Agricultural Sciences*, *Biology & Biochemistry*, *Environment/Ecology*, *Molecular Biology & Genetics*, *Pharmacology & Toxicology* and *Plant & Animal Science*. Indeed, a review of journals through the ***Scopus*** database, where articles pertaining to contemporary entomological research are published, verifies the diversity of publication outlets for entomological research. The comparative analyses of India's research output in terms of the six science indicator fields mentioned latter are inclusive of the research output in entomology. However, the precise contribution of entomological research papers in India's share of world output cannot be estimated from this data.

Given below is India's share of world output in each indicator field including entomological research. **Table (1)** gives a broad overview of the growth of Indian scientific output in the six indicator fields that include topics under the research area of entomology.

Table 1: India's share of world output in each indicator field including entomological research

Scientific indicator field	***2005***	***2014***
Agricultural Sciences	6% (approximately)	7.5% (approximately)
Biology & Biochemistry	2.43%	5.42%
Environment & Ecology	2.74%	3.98%
Molecular biology & Genetics	1.33%	2.62%
Pharmacology & Toxicology	3.20%	6.37%
Plant & Animal Science	2.87%	3.32%

Source: (India's Research Output and Collaboration (2005-14): A Bibliometric Study, 2015)

The comparative analysis shows an increase in the share of world output in all the scientific indicator fields suggesting a growth in the volume of Indian scientific literature. This corresponds to the empirical findings of the present study obtained from the Scopus database confirming that the number of publications in Entomology from India has shown an increase from the mid-1990s.

4.5. Relevance of entomological research in the north-east region

The recent decades have seen a renewed interest in the field of entomology. The growth of entomology as a discipline follows a trajectory that originates in the ancient world and continues, unbroken into the present modern times. This branch of the biological sciences has now become an exact science that offers to find solutions to some of the most practical problems afflicting the world today.

The study of insects has been of utmost importance to the field of agriculture. This contribution arises from research activities carried out in areas like *economic thresholds and pest management*, *pesticide formulation*, *global warming and pest out-breaks*, and *apiculture* to name a few. These research areas can be subsumed under a broader term called ***economic***

entomology, which is a branch of entomology that deals with the study of insects beneficial for or harmful to human beings. Controlling of pestiferous insects, and the farming and utilization of friendly insects, including their products, form an essential part of agricultural activities.

There are several other branches of entomology that are indispensable in ensuring adequate standards to and convenience of human life. The fields of ***medical and veterinary entomology***, ***forest entomology***, ***environmental entomology*** are some of the fields which have significant implications for society. The diversity of the research areas that the discipline of entomology has come to embody is what makes it an interesting case for study.

4.6. Entomology in S&T organizations in the north-east

The literacy rate in the north-eastern states is 79.64, more than the national average of 74.04 (www.mdoner.gov.in). However, the infrastructure for research and development (R&D) in science and technology is not well established in this region. Most of the R&D activities are concentrated within a few scientific institutions. A preliminary analysis of articles published in journals indexed in the Scopus database has been utilized to determine the organizations engaged in Entomological research in the north-eastern states of India. These include, universities, government-laboratories and research institutes. There are, however, very few Non-Governemetal Organiztions (NGOs) active in R&D in the region.

Table (2) and **Table (3)** give a list of the universities and research organizations involved in research in the area of Entomology in India. These are shown in the next section.

Table 2: The list of universities having at least one publication in the area of Entomology from 1975-2016

STATE	UNIVERSITY	YEAR OF ESTABLISHMENT
Arunachal Pradesh	1. Rajiv Gandhi Univesity, Itanagar (Central University) 2. College of Horticulture and Forestry, Pasighat (Central Agricultural University, Imphal)	1985 1992
Assam	1.Assam University, Silchar (Central University) 2. Tezpur University, Tezpur (Central University) 3. Assam Agricultural University, Jorhat (State University) 4.Dibrugarh University, Dibrugarh (State University) 5.Gauhati University, Guwahati (State University)	1989 1994 1969 1965 1948
Manipur	1.Manipur University, Imphal (Central Univesity) 2.Central Agricultural University, Imphal (Central University)	1980 1992
Meghalaya	1.North Eastern Hill University, Shillong (Central University) 2.College of Home Science, Tura (Central Agricultural University, Imphal) 3.College of Post-Graduate studies, Umiam (Central Agricultural University, Imphal)	1973 1992 1992

Mizoram	1.Mizoram University, Aizwal (Central University)	2001
Nagaland	1.Nagaland University, Kohima (Central University)	1989
Sikkim	1.Sikkim University, Gangtok (Central University)	2006
Tripura	1.Tripura university, Agartala (Central University)	1987

Table 3: The list of government laboratories and research institutes having at least one publication in Entomology from 1975 to 2016 (April)

STATE	RESEARCH ORGANIZATION	YEAR OF ESTABLISHMENT
Arunachal Pradesh	-	-
Assam	1. The Institute of Advanced Study in Science and Technology 2. CSIR-North-East Institute of Science and Technology 3. Rain Forest Research Institute 4. Regional Medical Research Centre-NE region, Indian Council of Medical Research,Assam 5. Department of Biotechnology, Indian Institute of Technology, GuwahatiJorhat Institute of Science and Technology 6. Defence Research Laboratory, Defence Research and Development Organization, Assam 7. Tocklai Tea Research Institue 8. Central Muga Eri Research and Training Institute	1979 1961 1988 1982 2002 1962 1911 1972
Manipur	1. Institute of Bio-resources and Sustainable Development,Department of Biotechnology, Government of India 2. North-East Institute of Science and Technology (CSIR), Substation, Imphal	2001 1961

Meghalaya	1. ICAR Research Complex for NEH Region 2. Central Potato Research Station	1975 1959
Mizoram	1. Division of Agricultural Entomology, ICAR Research Complex for NEH Region	1975
Nagaland	-	-
Sikkim	1. ICAR- National Research Centre on Orchids	1996
Tripura	-	-

From the list of the organizations involved in entomological research in the north-eastern region of India given above, certain important inferences can be derived. For an area of its size, there are very few scientific organizations involved in scientific research within the region. Most of the organizations are universities and some states have only one university for higher learning. Established government laboratories are also very few in number within the region. The distribution of scientific institutions within the north-eastern region is also highly uneven. A majority of the scientific institutions are located in a single state, the state of Assam. This indicates that there is a tremendous scope for the improvement of infrastructure for the promotion of higher learning and research and development in science and technology in this region.

4.7. Journal Distribution

This study includes research papers, conference papers, short surveys and reports published in the journals indexed by the Scopus database. A preliminary survey of the journals that publish scientific results of entomological research from the north-east region reveals that most of these journals are international journals. This finding is expected as the Scopus database is an international abstract and journal indexing database. Domestic journals, although prolific in number, often do not meet the criteria for being listed in the Scopus database.

Another interesting observation that emerges from the review of these journals is that the journals where the results of entomological research are published cover a broad range of research areas. A list of the journals that published articles from the north-east from the year 2015 to the month of April, 2016 is given as under. Only one journal among those listed below is an Indian journal - ***Journal of Postgraduate Medicine***.

- Tropical Ecology
- International Journal of Tropical Insect Science
- Zootaxa
- PLoS ONE
- Saudi Journal of Biological Sciences
- Turkish Journal of Zoology
- Parasites and Vectors
- Applied Entomology and Zoology
- BMC Public Health
- The American journal of tropical medicine and hygiene
- Acta Tropica
- Journal of Infection and Public Health
- Potato Research
- Acta Phytopathologica et Entomologica Hungarica
- Journal of Asia-Pacific Entomology
- Clinical Ophthalmology
- Zoology and Ecology
- Transactions of the Royal Society of Tropical Medicine and Hygiene
- Advances in Virology
- Journal of Postgraduate Medicine
- Veterinary World

The titles of the journals give a broad indication of the research areas that they encompass. This indicates that entomology has developed into a scientific field that includes a variety of approaches to find solutions to the practical problems facing humankind. It is no longer limited to the traditional approach of studying insect but has developed into a field that is at the frontier of biological research.

4.8. Internet and scientific R&D in the north-east

One of the primary aims of this study is to understand how the Internet and the internet-based means of communication have affected scientific research in the north-east region of India. Access to the Internet or the World Wide Web is not just a matter of having an internet connection but is a matter of equality among the users of this technology(DiMaggio and Hargittai 2001). This includes equal access to the hardware and software components of internet technologies as well as access to a reliable connection. This section aims at analysing the level and the nature of internet connectivity and access in the north-eastern region of India.

A recent article written in the year 2013, estimated the number of internet users in the north-east at 0.1 million(Rao 2013). This is about 0.2% of the total population in the region. This limited use of the internet in the region indicates certain underlying infrastructural lapses to promote the adoption and the use of ICT in the region.

The internet connectivity to the north-eastern states was through the city of Chennai in the southern region of India through one of the two international internet gateway until March 2016 (Ali 2016) . This involved connectivity through a very large distance which compromised the speed and the continuity of internet connections to the region. However, in the month of March 2016, agreements between the government of India and the government of Bangladesh, a neighbouring country of India, have materialized to provide internet connectivity from international internet gateway in Cox Bazaar in Bangladesh (Ali 2016). This location is closer to the north-east than the southern state of Chennai and it is expected that internet accessibility in the region will improve significantly as a result.

However, improved internet accessibility has to be coupled with improvements in the infrastructure of scientific organization in the region in order to enable efficient utilization of the advantages of the internet. This would include funding mechanism to improve the digital infrastructure of the scientific organizations. An estimation of the technological capability of internet adoption is outside the scope of this study. But this study indeed paves the way for further research on improving communications technology in the north-eastern region in order to facilitate scientific research and scientific collaboration.

Chapter 5

Scientific Collaboration: Empirical findings

In the previous chapters, the concepts of scientific collaboration, proximity and the role of the Internet in promoting collaborative scientific research have been discussed at length. This chapter provides the empirical analysis of results obtained from the primary data collected through emailed survey of the select scientists working in universities and other teaching and research institutions located in the north eastern states of India. This chapter is arranged under two sections: the first section deals with the results from the scientometric analysis of jointly authored publications originating in the eight north-eastern states of India. These publications include journal articles, reviews, conference papers, short surveys and reports. The second section elaborates on the findings from the *e-mail questionnaires* sent to Entomologists in the region. The final section highlights the key findings of the research.

5.1. Co-authored publications and scientific collaboration

As has already been mentioned in *Chapter 2*, the co-authored publications have been found to be used extensively in the related literature as a measure of scientific collaboration. This study has taken joint publications in Scopus-indexed journals as the unit of analysis. Although the publications include journal articles, reviews, conference papers, short surveys and reports, a majority of the published output isin the form of journal articles. The first co-authored publication in Entomology to be published from North-east India in a Scopus-indexed journals an article published in the *International Journal of Acarology* in 1975. This publication was an outcome of collaboration at the national level between two agricultural universities; the **Punjab Agricultural University** in the northern state of Punjab and the **Assam Agricultural University** in the north-eastern state of Assam. Therefore, 1975 has been taken as the base year and all publications thereafter, between the years 1975 and 2016 (till the month of April), have been analyzed in this study.

Table (1) gives a state-wise distribution of publications in Entomology between the years, 1975 to 2016 (till the month of April) originating in the north-eastern region of India.

Table 1: Co-authored publications in Entomology in the states of North-east India

State	Total number of research organizations	Total no. of publications	Local (Intra-state)	Regional (Inter-state)	National	International	Single-author publications
Arunachal Pradesh	2	15	1	2	2	8	2
Assam	14	267	162	23	48	30	4
Manipur	4	42	21	5	13	3	0
Meghalaya	5	52	19	7	12	14	0
Mizoram	2	38	11	3	20	3	1
Nagaland	1	9	2	1	3	1	2
Sikkim	2	18	4	6	7	1	0
Tripura	1	40	20	4	2	13	1
Total	31	481	240	51	107	73	10

Source: Scopus Database

Table (1) gives an indication of the collaborative practices of the scientists in the north-eastern region from 1975 to 2016 (till the month of April). Around 481 publications have been published in Scopus-indexed journals during this period. About 98% of the publications that have been published are co-authored publications, with only 10 being single-author publications. A total number of 471 publications have been analyzed in this study. It can also be seen from the table above that the state of Assam accounts for approximately 55% of the total published output in Entomology from the north-eastern region. It is followed by the state of Meghalaya which accounts for around 11% of the regional publication productivity in Entomology. The states of Manipur and Tripura account for 8% and 9% of the regional productivity, respectively. The number of publications from the north-east region is a small fraction of the national scientific output in Entomology. In the period between 1975 and 2016 (till the month of April), around 11,296 publications in Entomology were published from India in Scopus-indexed journals. The contribution of the north-east region to this national scientific output is approximately 4.26%.Although this contribution is small in terms of quantitative output, an important observation to be made here is that the number of co-authored publications in Entomology from the north-east region has been steadily increasing since the mid-1990s. This corresponds with the growth in the national scientific output in Entomology in terms of publications after the mid-1990s. The increase in the number of co-authored publications across the time period of publication is shown in **Table (2)**. The year 1975 has been taken as the starting year for analysis due to the fact that the first publication in Entomology to be published in a Scopus-indexed journal was in 1975.

Table 2: Temporal distribution of published output in Entomology

State	**1975-1984**	**1984-1994**	**1995-2004**	**2005-April 2016**
Arunachal Pradesh	0	0	0	13
Assam	1	4	40	217
Manipur	0	0	11	31
Meghalaya	0	0	4	48
Mizoram	0	0	0	37
Nagaland	0	1	0	6
Sikkim	0	1	0	18
Tripura	1	3	15	20
Total	2	9	70	390

Source: Scopus Database

From **Tables (1) & (2),** it can be concluded that the Entomologists in North-east India are increasingly collaborative. This is evident from the large number of co-authored papers published in Scopus-indexed journals, as opposed to single-authored papers. The number of co-authored papers published has also increased over time. It is seen that the number of publications show a significant increase in the periods between 1995 and 2004, and between 2005 and 2016. This indicates that Entomologists in the north-eastern region have become increasingly involved in collaborative research over the decades.

Collaboration can be of various types (Katz and Martin, year, p.). One of the primary aims of this study was to identify the patterns of collaboration within the scientific community under study. Four levels of collaboration have been investigated in the present study-local (intra-state), regional (inter-state), national and international levels of collaboration. The relative number of jointly published papers with collaborative partners located at different geographical locations can provide an understanding of the constraints that geographical separation imposes on collaboration in a peripheral region of India. **Table (3)** gives the patterns of collaboration among Entomologists in the region in terms of percentage of the total number of publications.

Table 3: Pattern of Collaboration based on co-authored published between 1975 and April 2016

Type of Collaboration	Total Number of Publications (%)
Local	50.74
Regional	10.83
National	22.93
International	15.50

Source: Scopus Database

From the above table, it becomes evident that Entomologists in the north-eastern region of India collaborate mostly at the local level, i.e., within their respective states. Approximately, 51% of the co-authored publications are by collaborative partners belonging to the same state within the region. The second most frequent type of collaboration among Entomologists in the north-eastern region is at the national level. Publications co-authored with collaborative partners from states outside the north-eastern region account for almost 23% of the total number of publications. International collaboration is the third preferred type of collaboration accounting for 15.50% of the total published output. Regional collaboration involving collaborating partners based in other north-eastern states is the least preferred type of collaboration, accounting for only about 11% of the co-authored publications.

The above findings give a preliminary insight into the collaborative practices of a particular community of scientists in a peripheral region of India, namely, the north-eastern region of India. The above results indicate that the geographical distance does play a role in the collaborative practices of Entomologists in the region. With advances in information and communications technology (ICT) like the Internet and the *World Wide Web,* the challenges posed by geographical distance on collaboration, especially non-collocated collaboration could be mitigated This potential has been discussed in Chapter 3. However, an assessment of the potential benefits of the Internet in facilitating scientific collaboration requires taking into account the views of the scientists themselves. The next section deals with the findings obtained from the *email questionnaire* sent to the select scientists actively involved in Entomology research in the north-eastern region.

5.2. Internet and scientific collaboration in North-east India

The email questionnaire method is an effective method of data collection when there is a need for covering a wide geographical area (May 2011). It also lowers the cost of conducting the research (May 2011). Due to these specific advantages, the email questionnaire method was chosen in the present study to conduct opinion research. The questionnaire was sent to Entomologists in the north-eastern region of the country through email, instead of postal mail, as this is a faster and more cost effective method of data collection. The sample comprises 54 active researchers in the field of Entomology in the region. There were 16 respondents allowing a response rate of 29.62% (approximately 30%). The *email* questionnaire contained questions that addressed the following issues - accessibility to the Internet in the workplace, the nature of Internet use, use of the Internet in collaborative activities and the use of the Internet as a means of communication with collaborative partners. The aim of the questionnaire was to seek the opinion of research in order to understand their views about the importance of the Internet and the *World Wide Web* in facilitating joint scientific work.

Of the 16 respondents, a majority were involved in collaborative research. The type of collaboration most preferred by the respondents was the national level of collaboration. This was in contrast to the previous findings from the scientometric analysis of co-authored publications which shows that collaborations at the local level involving partners belonging to the same north-eastern state should be the most preferred type of collaboration. However, owing to the small sample size of the questionnaire survey, more elaborate studies need to be conducted before arriving at a concrete conclusion. Internet accessibility is a determining factor in understanding the impact of internet technologies on scientific research. All the 16 respondents reported having access to the internet from their workplace. However, as has already been discussed, internet accessibility is not only a question of “have” or “have not” representing a “digital divide”. The question of accessibility is better represented by the concept of “digital inequality”, which also takes into account inequalities among persons with formal access to the Internet (DiMaggio and Hargittai 2001). This includes inequality in access to reliable hardwares, softwares and connections.

Majority of the respondents in this study have rated the internet connection in their workplace as being “good”. A small fraction has reported having “very good” internet connectivity from their workplace. The remaining respondents have rated the internet connectivity from their workplace as being “average”. This difference in the responses indicates the variance in the level of the reliability and continuity of internet connections among the institutions in which the scientists work. This finding can be corroborated with insights from telephonic conversations with the concerned scientists originally meant as a follow-up to the mailed questionnaire seeking timely responses. Some of the scientists reported to having no internet connection in their institutions for almost a week, explaining the delay in their responses to the email questionnaire. During a telephonic conversation, one of the respondents responded as follows:

“I am really sorry that I have not been able to respond to your email questionnaire. The problem is that there is no internet connection in our university (Tripura University) for the past week. I will fill up the questionnaire as soon as Internet connection is restored.”

This confirms the argument that the question of accessibility to the Internet is not just about having a computer and a live internet connection but also about the continuity and the speed of the internet connection.

Most of the respondents of this study use the Internet for research activities. The use of the Internet for communicating with colleagues and for the seeking and retrieval of relevant information is given equal importance by the respondents. However, dissemination of research results through the Internet is considered as less important for scientific research activity by the respondents. All of the respondents consider the Internet useful in conducting collaborative research work. The most important reason given for this is that the Internet helps in keeping the scientists well informed about the latest developments in their fields. A large majority of the scientists feel that the Internet is important in facilitating communication with their collaborative partners. A few scientists also felt that the Internet helped them in the dissemination of their research results. All the respondents have reported maintaining communications with their collaborative partners through the Internet. The *email* is the preferred mode of communication through the Internet. All the respondents have reported using the *email* for communication most often. A majority of the respondents use the Internet in communicating with their collaborative partners more than once a week.

All the above findings imply that the Internet has come to play an important role in contemporary research among the Entomologists in the north-eastern region of India. However, the role of the Internet in facilitating joint scientific work becomes all the more relevant for non-collocated collaboration. One of the major challenges in non-collocated collaboration is the coordination of activities between collaborating partners. This can be accomplished through effective communication between partners. In order to achieve effective communication between partners there must be regular face-to-face communication between the scientists. This, on the other hand, increases the economic costs and costs in terms of time of collaborative research. An alternative to face-to-face communication is provided by the internet based means of communication. This form of communication enables interaction across geographical distances and time. There has been a certain amount of speculation that computer-mediated communication may eliminate the need for face-to-face communication. This would make it possible to have effective communication without meeting in person. This would naturally imply that the physical barrier to collaboration across distances would be completely overcome. However, the literature suggests that the need for face-to-face communication cannot be completely overcome by computer-mediated communication. This argument has also been confirmed in the present study.

The respondents of this study were divided over their opinions on whether internet based means of communication or computer-mediated communication can replace the need for face-to-face communication. Almost half of the number of respondents felt that the Internet can replace the need for face-to-face communication. The other half held the opposing view.

To our question as to why the scientists think internet-based means of communication can replace face-to-face communication, the following responses were obtained from five different scientists:

"It is a tool to specify our needs easily and the collaborator can understand our needs to speed up our research."

"We have the technology. It is only a matter of changing our mindsets."

“It is a cheap and instant mode of communication where the record of communication can be retrieved anytime and anywhere.”

“From Tripura, due to communication problem and also to save money, communication through internet is much better.”

“We can put our ideas without hesitation through emails.”

In response to the request to specify why the respondents think that internet based means of communication cannot replace face-to-face communication, the following responses were obtained from three different Entomologists:

“Face to face communication is vital in the long run.”

“Face to face communication can be a better way of interaction with colleagues.”

“Face to face communication is more better because more discussion can be done than over e-mail.”

The above statements from the respondents suggest that there is a difference in the perception of the Internet as a tool for communication. Almost half of the respondents questioned through the email questionnaire report have reported that they do not have face-to-face communication with their collaborating partners. The remaining respondents were engaged in communication through the internet in addition to face-to-face communications.

The respondents were also asked about the kinds of challenges they face in conducting collaborative research. The factor which was deemed to be most challenging was the lack of resources and funding for conducting joint scientific research. The other factors co-ordination costs, extra-time costs, nature of international treaties and government funding and administrative formalities and red-tapism proved to be less significant. On being asked to specify any other challenges faced by them, we got the following responses:

“Improve internet facility in the region.”

“Except DBT twinning program no other agency is promoting the collaborative research.”

“Lack of resource and Funding”

“Local Public involvement is more effective in all the work.”

“Facing official paper problems”

These statements point out that lack of funding and resources in promoting collaborative research is a major challenge to scientific collaboration in the north-eastern region of India. It is also interesting to note that one of the respondents suggested the “internet facility” or the infrastructure for internet use must be improved for in the region in order to reduce the hurdles to collaborative research. This lays emphasis on the perception of the importance of the Internet in initiating and maintaining collaborative projects. On the question of whether the Internet was helpful in overcoming these challenges, a majority of the respondents responded with an affirmative response.

On being asked to specify how the respondents think Internet is helpful in overcoming the challenges to collaborative research the following responses from six different respondents were obtained:

“Some work done is easy way.”

“Contact the resource persons easily and tap the sources accordingly.”

“Red-tapism and other administrative formalities are necessary irritants.”

“Internet is a very rapid process, saves time, money, every information received quickly, if internet access is there.”

“Immediately information transfer to all the colleagues.”

“Communication (of) information immediately.”

However, one of the respondents was of the opinion that the Internet cannot mitigate the challenges of collaboration:

“Internet can only communicate digital form of information, it is incapable to compensate for actual physical examination.”

It may be deciphered from these responses that there was a high level of optimism centred on the use of the Internet in facilitating collaborative research among the Entomologists located in the north-eastern region of India. All the respondents felt that Internet is essential for maintaining collaborative research. Most of the respondents hold the view that the good quality of internet accessibility is the most important for the national and international collaborations. Regional collaborations appear to be of less importance to the scientists.

5.3. Findings

This chapter gives an account of the empirical findings obtained from quantitative as well qualitative methods of data collection. The major findings from this study are as follows. First, the scientometric analysis of co-authored publications shows that Entomologists in the north-eastern region of India are becoming increasingly collaborative. This is evident from the rise in the number of co-authored publications in the time-period analyzed. Second, Entomologists in the region collaborate most extensively at the local level with partners who belong to the same state. This is followed by collaboration at the national level, and then at the international level. This suggests that geography plays a an important role in determining the choice of collaborative partners among Entomologists in the region. Third, at the regional level of collaboration, i.e., collaboration involving scientists located within the eight north-eastern states, instances of scientific collaboration measured through jointly authored publications are the lowest in number. This suggests that geographical proximity alone cannot be a sufficient condition for collaboration to take place(Reference). The other dimensions of proximity, mainly, cognitive, organizational, institutional and economic proximity also have a role in determining the initiation and maintenance of scientific collaborations.

Fourth, while all the respondents in this study report having access to the Internet, this connectivity varies among institutions. Although internet connectivity in the workplace has been reported to good in the work place, telephonic conversations with scientists implies that there are periods of extended internet connectivity failure. Fifth, Entomologists vary in their opinion on the ability of the Internet to replace the need for face-to-face communication. While there is a general sense of optimism about the use of the Internet for communicating with geographically dispersed collaborative partners, the need for face-to-face communication is still felt by some of the respondents. Sixth, the need to promote collaborative research has been emphasized by a majority of the scientists, especially in relation to the funds and resources available for collaborative research. A respondent was of the opinion that the Internet connectivity of the region should be improved to promote collaborative research in the region. This suggests that the need of the Internet in research is felt in the periphery of India. Finally, all the respondents feel that the Internet is essential in maintaining collaborative projects, especially at the national and international level, suggesting its impact on collaboration across large distances. Scientific collaboration at the regional level continues to receive limited attention from the Entomologists.

Chapter 6

Conclusion

Scientific collaboration is known to be affected by several social, economic, political and scientific factors. The notion of proximity is one such factor that plays a major role in determining instances of scientific collaboration. The various dimensions of proximity and the relations between them have been discussed in Chapter 2. However, as has been described, the role of the geographical dimension of proximity on scientific collaboration has been studied exclusively in the present study. This analytical isolation of the effect of geographical proximity on scientific collaboration has been carried out in order to determine whether spatial proximity indeed matters for the process of scientific collaboration.

As has been discussed in Chapter 3, the literature suggests that advancements in transportation technologies and the revolutionary developments in communication technologies have changed the way that distance is perceived. With the decreasing costs and the increasing ease of transportation across large distances, the mobility of scientific personnel for the purposes of collaboration has become more commonplace than it was a few decades ago. This has given rise to the concept of temporary geographical proximity (TGP). Communication across distances has been greatly facilitated by computer-mediated communication. Studies have shown that scientists use internet-based means of communication like the electronic mail and videoconferencing to communicate more and more with their collaborative partners. These developments have special significance for scientists in the developing countries. TGP supported by internet-based means of communication can not only mitigate the problems of long-distance collaboration but can also result in successful integration of developing countries scientists into the international scientific network thereby, democratizing access to information and the production scientific knowledge.

The aim of the present study was to understand the patterns of collaboration within a select scientific community of entomologists located in geographically remote region of India. The effect of the geographic dimension of proximity on the pattern of collaboration was investigated through the analysis of co-authored publications. In order to assess whether the advancements in communications technologies have had an impact on scientific research and knowledge production in this remote part of the world, an opinion survey was conducted among entomologists actively involved in entomological research. The major findings from this study have been discussed in the previous chapter. The aim of the present chapter is to discuss the implications of these findings.

The first important finding from the scientometric analysis of co-authored publications shows that Entomologists in the north-eastern region of India are becoming increasingly collaborative. This is reflected by the large number of jointly authored publications listed in the Scopus-indexed journals. However, it must be kept in mind that publications listed in the Scopus international database does not account for all the publications co-authored by entomologists in the region. This is because many domestic journals are not listed in the Scopus database. Thus, a large proportion of the published output remains unanalyzed. An analysis of publications from more inclusive sources could greatly affect the findings of the research. Scientists in the developing countries are known to find it easier to publish in domestic journals in comparison to international journals. This is often due to the higher standards for publication in international journals in terms of methodology adopted and the validity and scope of the research questions chosen. Scientists from developing regions, especially from peripheral regions may not have the infrastructure to alter the quality of their research to meet international standards. The nature of the research questions may also be of more local importance. Hence, developing countries scientists find it easier to publish in domestic journals. This implies that publications in domestic journals must also be analyzed to gain a more holistic picture of collaborative trends in entomological research in North-East India.

Second, Entomologists in the region collaborate most extensively at the local level with partners who belong to the same state. One important implication of this finding is that geographical proximity appears to play an important role in the selection of partners among entomologists in the region. This can be explained in terms of the convenience of arranging face-to-face meetings with collaborative partners. However, as has been discussed in Chapter 4, internet connectivity in the north-east region is still not uniform in terms of accessibility. It would be interesting to observe how the pattern of collaboration in the region would be affected once uniform and uninterrupted access to the Internet is established in the region.

Third, the percentage of collaboration at the regional level among entomologists in the region is lower than the percentage of national and international collaboration as measured from jointly-authored publications. This finding is contrary to expectations. If geographical proximity were the only factor determining the initiation and the maintenance of collaboration, then instances of regional collaboration should have outnumbered instances of national and international collaboration. This implies that although proximity in terms of distance plays a major role in deciding the possibility of collaboration in the north-east region, it is not the only factor. The roles of the other dimensions of proximity in facilitating scientific collaboration have to be accounted for at this stage. Two major dimensions of proximity may play a role in determining the low preference of regional collaboration among entomologists in the region – cognitive and organizational proximity. The social and institutional dimensions of proximity have been ruled out due to the following reasons. Social proximity as characterized by trust-based relationships is not confined to territory. Social relations are possible to be established between individuals regardless of their location. However, as has been discussed in Chapter 2, social proximity is facilitated by geographical proximity. If at all social proximity plays a role in establishing collaborations in Entomology in the north-eastern region of India, this would be effective only at the local, intra-state level as seen from the pattern of collaboration in the region. Institutional proximity cannot have a significant impact on collaboration in the region as scientific organizations in the region are likely to have similar formal institutions like rules and regulations. The informal institutions of culture and habit are also likely to vary among the eight states. The cognitive dimension of proximity could, however, play a major role as scientists may find intellectual companionship in scientists conducting similar research outside the region. Organized proximity as characterized by the facilitation of relations between actors within and between organizations is not limited to geographical boundaries. This may have an effect on the pattern of collaboration observed in the region.

Fourth, while all the respondents in this study report having access to the Internet, the connectivity varies among research institutions. This implies that although scientists have a functional internet connection in their offices, the reliability of this connection is questionable. This stresses the argument that internet access is not just a question of "have" and "have not" but also a matter of equality in terms of access to reliable hardwares, softwares and connection. When the connectivity to the internet is not consistent, accessibility of the advantages of internet is impaired. This translates into a negative impact on the research activity, including scientific collaboration across distances. This non-uniformity of internet access in the region could also be a factor resulting in the low percentage of regional collaboration in the north-eastern region.

Fifth, Entomologists vary in their opinions on the ability of the Internet to replace the need for face-to-face communication. It has been seen that while many scientists feel that internet based means of communication can indeed replace face-to-face communication others feel that face-to-face meetings are indispensable for the collaborative process. The costs of arranging face-to-face meetings for collaborative projects are higher for peripheral scientists. Thus, scientists tend to be optimistic about the ability of the internet technologies to minimize these costs. As has been shown in the literature, due to the tacit dimension of scientific knowledge, face-to-face communication will always remain an essential part of the collaborative process. It must be emphasized here that face-to-face communication does not necessarily imply that participants always be collocated. The concept of TGP can provide an alternative to permanent collocation in remote collaborations. This can be supported by internet-based means of communication during the stages in which teams choose to undertake long-distance teamwork.

Sixth, a majority of the respondents in the opinion survey expressed the need to promote collaborative research in the region. This was in special relation to the availability of funds and resources for collaborative research. One of the respondents also suggested that internet connectivity in the region needs to be improved in order to facilitate collaborative research. This finding suggests that scientists in the region are keen to be involved in collaborative research work.

Finally, all the respondents felt that the Internet is essential in maintaining collaborative projects, especially at the national and international level, suggesting its impact on collaboration across large distances. Scientific collaboration at the regional level continued to receive limited attention from the Entomologists. This suggests that entomologists in the region are keen to use the internet technologies for conducting joint scientific research across large distances.

Some policy perspectives emerge from the findings of this study and their implications for collaborative research in the north-eastern region. Scientific collaboration as an important mode of knowledge production needs to be promoted at all levels in the region. This can be achieved by emphasizing on policies to improve the funds allocated to collaborative research in the region as well as by assisting scientists in establishing contacts with scientists from other parts of the world. This would mean a focus on the organizational dimension of proximity.

A second policy perspective would concern the connectivity initiative. Internet connectivity in the region needs to be improved and reliability of the connections upgraded. This would enable the scientists in this region better utilize the advantages of the Internet in conducting scientific activities. This would also improve the possibility of initiating collaborations with partners across different parts of the world and thus, integrating the scientists into the global scientific community. The scientists would be able to contribute to the production of novel scientific knowledge production through their specialized knowledge ensuring the participation of this peripheral community of scientists in global production of scientific knowledge.

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Appendix

Email-Questionnaire

Internet use and long-distance collaboration:
A case study of Entomologists in North-East India

This questionnaire is aimed at understanding the perception of scientists, specifically involved in the north-eastern region of India, about the impact of the Internet in on research collaboration across geographical distances. The information provided here will be solely used for academic purposes. Thank you, for your time and your kind co-operation.

Part I: Internet use in collaborative research

Please tick the appropriate response(s) and fill in the details wherever necessary.

1. Have you been involved in collaborative research?
   - Yes
   - No

2. If yes, what are the types of collaborative research you have undertaken, so far?
   - Inter-departmental
   - Inter-institutional
   - Regional (within the North-East Region)
   - National
   - International

3. Do you have Internet-accessibility in your workplace?

    - Yes
    - No

4. How would you rate the accessibility of Internet in your workplace?

    - Very good
    - Good
    - Average
    - Bad
    - Very bad

5. Have you used the Internet for research and development (R&D) activities?

    - Yes
    - No

6. If yes, what do you mostly use the Internet in R&D activities for?

    - Communication with colleagues
    - Internet-based search and retrieval of information
    - Dissemination of research results through the World Wide Web

7. Do you find the Internet useful in conducting collaborative research?

    - Yes
    - No

8. What are the reasons for you to think so?

- Internet helps me to communicate better with my collaborating partners
- Internet helps me in staying up-to-date about recent scientific developments
- Internet helps me in disseminating information about the results of my research

9. Do you communicate with your collaborating partners through the Internet?

- Yes
- No

10. If yes, which channel of communication do you use most often?

- Electronic mail (email)
- Chatting
- Video-conferencing

11. How often do you use the Internet to communicate with your collaborative partner(s)?

- Less than once a week
- Once a week
- More than once a week

12. Do you have face-to-face communication with your collaborative partner(s)?

- Yes
- No

13. Do you think that communication through the Internet could replace face-to-face communication?

- Yes
- No

14. Please, specify your reason.

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Part II: Challenges of collaboration

15. Have you faced any challenges in maintaining collaborative projects?

- Yes
- No

16. If yes, which of the following factors do you think is the most challenging?

- Co-ordination costs
- Extra-time costs
- Lack of resources and funding
- Nature of international treaties and government funding
- Administrative formalities and red-tapism

17. Please, specify others if not mentioned above.

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…………………………………………………………………………………………
…………………………………………………………………………………………

18. Do you think Internet is helpful in overcoming these challenges?

- o Yes
- o No

19. Please, specify your reasons below.

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……………………………………………………………………………………………
…………………………………………………………………………………………….

20. Do you think the Internet is necessary in sustaining collaborative projects?

- o Yes
- o No

21. If yes, which type of collaboration do you think requires accessibility to the Internet the most?

  - o Inter-departmental
  - o Inter-institutional
  - o Regional (within the North-East Region)
  - o National
  - o International

Part III: Details of on-going collaborations

22. Number of on-going collaborations

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23. Institutional affiliation(s) of current collaborative partner(s)

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Part IV: Personal details

24. Organization to which you are affiliated

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25. Department in which you work

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26. Date of birth

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27. Sex

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28. Marital status

- Married
- Unmarried

29. Educational qualifications

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THANK YOU