Canada reaching out?

A Study of Collaboration between Canada and the Emerging Economies in Health Biotechnology

By

Monali Ray

A dissertation submitted in conformity with the requirements for the Degree of Doctor of Philosophy

Institute of Medical Science
University of Toronto

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2011

Abstract

This dissertation discusses research on Canada’s collaboration with emerging economies, specifically Brazil and India, in the field of health biotechnology. In recent years Canada has shown interest in engaging with emerging economies including Brazil and India in S&T fields. However, little is known about the levels and characteristics of such collaboration. Without greater understanding of this phenomenon it is difficult to inform public policy on how to best encourage collaboration. In this dissertation, the levels of Canada-emerging economies research and entrepreneurial collaboration are gauged. The motivations driving Canada-emerging economies research as well as entrepreneurial collaboration, its challenges and outcomes are examined. The roles of wider institutional actors – funding agencies, intellectual property experts, regulators, etc – in both Canada and the two emerging economies that support international collaboration are analyzed. The research reveals that north-south collaboration in health biotechnology has the potential to lead to a wide range of scientific and commercial benefits for both partners. They include access to expertise, technologies, biodiversity,
as well as increasing potential to publish in high impact journals. The benefits are mutual. Northern academics and entrepreneurs are not necessarily in a dominant position in the partnerships, thus contradicting stereotypical notions of partners in north-south relationships. The systems of innovation conceptual framework is useful to uncover how institutions in both the north and the south shape S&T collaboration, and also to develop multi-pronged policy approaches to promote such partnerships and mitigate risks. The framework enables moving away from a donor-recipient, linear model of S&T interactions between the north and the south, and towards conceptualizing north-south collaboration as complex interplay of two innovation systems.
For

Sara Al-Bader and Michael Smoughton

With love
Acknowledgements

Without the support of many an exceptional soul, I would not have been able to write this dissertation. I would like to thank my supervisor, Halla Thorsteinsdóttir, for her constant encouragement and mentorship through the years. Her passion for inquiry is relentless, infectious. It has been a real pleasure and privilege to train under her. I thank my thesis committee members, Tim Westwood and Abdallah Daar for their questions and insight. Their advice has helped to strengthen the dissertation. My thanks are also extended to my examiner, Adam Holbrook, for his constructive criticism. A special thanks to David Wolfe for pointing me to good reads, and for being a most patient educator.

Much gratitude goes to my fellow doctoral students: Dominique McMahon, Billie-Jo Hardy, Rahim Rezaie and Kenneth Simiyu. They kept me going through the hardest of days with their comedy, courage and deep humanity.

Thanks to Dena Taylor and Ilana Mezhevich for their editorial guidance (‘syndissertation’ being a particularly memorable botch-up on my part). They were an encouraging test audience to early drafts. Eugene Vesely helped me with all sorts of computer-related emergencies, even on weekends.

Funding to carry out this project has been key. I thank the Canadian Institutes of Health Research, the Institute of Medical Science, University of Toronto, and the Shastri Indo-Canadian Institute for supporting me with their scholarships. The McLaughlin-Rotman Centre for Global Health generously provided home base.

My heartfelt thanks goes to all the scientists, entrepreneurs and policymakers in Brazil, India and Canada who took the time to meet with me and tell me about their experiences of collaboration. Their stories provide lessons of how southern and northern researchers work together to create knowledge that is exciting and inspiring.

I want to thank Hanna Kim, Amelia Makalintal, Grace Wang, Helen Bao, Liana Del Gobbo, Béatrice Séguin and Sarah Ali-Khan for cheering me on. They were often tricked into discussing my project over the phone, tea, drinks and sushi. Miraculously we are still on speaking terms. Maggi Al-Bader’s effortless charm and great kindness is a godsend.

I owe great thanks to my family for their love and support. Pallavi and Krzysztof Dziewa, Chirasree Dutta Ray and Rajarshi Ray gave me much needed perspective. They remind me everyday of what truly matters. Finally, I am deeply grateful to my parents, Malabika and Sujit Ray, for their appreciation for exploration, and for always supporting me in my dreams, no matter how wild.
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<td>All India Institute of Medical Sciences</td>
</tr>
<tr>
<td>ANVISA</td>
<td>National Health Surveillance Agency/\textit{Agência Nacional de Vigilância Sanitária}</td>
</tr>
<tr>
<td>API</td>
<td>Active Pharmaceutical Ingredient</td>
</tr>
<tr>
<td>AUCC</td>
<td>Association of Universities and Colleges of Canada</td>
</tr>
<tr>
<td>CAPES</td>
<td>Coordination for the Improvement of Higher Education Personnel/\textit{Coordenação de Aperfeiçoamento de Pessoal de Nível Superior}</td>
</tr>
<tr>
<td>CBD</td>
<td>Convention on Biological Diversity</td>
</tr>
<tr>
<td>cGEN</td>
<td>Council for Management of Genetic Patrimony</td>
</tr>
<tr>
<td>CIDA</td>
<td>Canadian International Development Agency</td>
</tr>
<tr>
<td>CIHR</td>
<td>Canadian Institutes of Health Research</td>
</tr>
<tr>
<td>CNPq</td>
<td>National Council on Scientific and Technological Development/\textit{Conselho Nacional de Desenvolvimento Científico e Tecnológico}</td>
</tr>
<tr>
<td>CONEP</td>
<td>National Ethics Committee/\textit{Comité Nacional de Ética em Pesquisa}</td>
</tr>
<tr>
<td>CRO</td>
<td>Contract Research Organization</td>
</tr>
<tr>
<td>CSIR</td>
<td>Council for Scientific and Industrial Research</td>
</tr>
<tr>
<td>CTO</td>
<td>Clinical Trial Organization</td>
</tr>
<tr>
<td>DAAD</td>
<td>German Academic Exchange Service/ ‘Deutscher Akademischer Austausch Dienst’</td>
</tr>
<tr>
<td>DAC</td>
<td>Development Assistance Committee</td>
</tr>
<tr>
<td>DBT</td>
<td>Department of Biotechnology</td>
</tr>
<tr>
<td>DFAIT</td>
<td>Department of Foreign Affairs and International Trade</td>
</tr>
<tr>
<td>DNA</td>
<td>Deoxyribonucleic Acid</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>DST</td>
<td>Department of Science and Technology</td>
</tr>
<tr>
<td>EMEA</td>
<td>European Medicines Evaluation Agency</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>FAP</td>
<td>State level foundation for the promotion of scientific research in Brazil</td>
</tr>
<tr>
<td>FAPESP</td>
<td>Foundation for Research Support of the State of Sao Paulo/‘Fundação de Amapro à Pesquisa do Estado de São Paulo’</td>
</tr>
<tr>
<td>FIOCRUZ</td>
<td>Fundação Oswaldo Cruz</td>
</tr>
<tr>
<td>FTAA</td>
<td>Free Trade Agreement of the Americas</td>
</tr>
<tr>
<td>GITA</td>
<td>Global Innovation and Technology Alliance</td>
</tr>
<tr>
<td>GNI</td>
<td>Gross National Income</td>
</tr>
<tr>
<td>HIV/AIDS</td>
<td>Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome</td>
</tr>
<tr>
<td>ICMR</td>
<td>Indian Council of Medical Research</td>
</tr>
<tr>
<td>IDRC</td>
<td>International Development Research Centre</td>
</tr>
<tr>
<td>INIST</td>
<td>Interdepartmental Network on International Science and Technology</td>
</tr>
<tr>
<td>IPR</td>
<td>Intellectual Property Rights</td>
</tr>
<tr>
<td>ISOP</td>
<td>International Strategic Opportunities Program</td>
</tr>
<tr>
<td>ISTPCanada</td>
<td>International Science &amp; Technology Partnerships Canada</td>
</tr>
<tr>
<td>ISTPP</td>
<td>International Science &amp; Technology Partnerships Program</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technologies</td>
</tr>
<tr>
<td>KFPE</td>
<td>Swiss Commission for Research Partnerships with Developing Countries</td>
</tr>
<tr>
<td>MDEIE</td>
<td>Ministry of Economic Development, Innovation and Export/’Ministère du Developpement economique, de’innovation, et l’exporation’</td>
</tr>
<tr>
<td>NAFTA</td>
<td>North American Free Trade Agreement</td>
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<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>NATO</td>
<td>North Atlantic Treaty Organization</td>
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<tr>
<td>NGO</td>
<td>Non Governmental Organization</td>
</tr>
<tr>
<td>NRC</td>
<td>National Research Council</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
</tr>
<tr>
<td>PCT</td>
<td>Patent Cooperation Treaty</td>
</tr>
<tr>
<td>RAWOO</td>
<td>Netherlands Development Assistance Research Council</td>
</tr>
<tr>
<td>RNA</td>
<td>Ribonucleic Acid</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>SARS</td>
<td>Severe Acute Respiratory Syndrome</td>
</tr>
<tr>
<td>Sida/SAREC</td>
<td>Swedish International Development Cooperation Agency/Swedish Agency for Research Cooperation with Developing Countries</td>
</tr>
<tr>
<td>SCI</td>
<td>Science Citation Index</td>
</tr>
<tr>
<td>S&amp;T</td>
<td>Science and Technology</td>
</tr>
<tr>
<td>TRIPS</td>
<td>Trade Related aspects of Intellectual Property rights</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom of Great Britain and Northern Ireland</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
</tr>
<tr>
<td>UNESCO</td>
<td>United Nations Educational, Scientific and Cultural Programme</td>
</tr>
<tr>
<td>US</td>
<td>United States of America</td>
</tr>
<tr>
<td>USSR</td>
<td>The Union of Soviet Socialist Republics</td>
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<tr>
<td>WTO</td>
<td>World Trade Organization</td>
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Chapter 1

Introduction

1.1 International collaboration in health biotechnology

Collaboration between developed and developing countries in health biotechnology can be critical to address global health challenges and to increase the innovation potential of the participants involved. In an increasingly globalized, interconnected world, developed (‘northern’) and developing (‘southern’) countries share health problems. Pathogens responsible for HIV/AIDS, influenza or SARS can rapidly cross national borders. The SARS virus, for instance, originated in a rural area in southern China in Fall 2002, and spread to countries including Canada, the US, Spain, Switzerland, Singapore, Brazil, India, Vietnam, Philippines and Mongolia within a few months time (Zhong & Wong, 2004). Also, lifestyle-related chronic illnesses such as cancer, diabetes and cardiovascular disease, which used to be associated with wealthier nations, are becoming prevalent in low-income countries. It was estimated that chronic diseases were responsible for 50% of the disease burden in developing countries in 2005, and the high burden of chronic illnesses will cost these economies $ 84 billion by the year 2015 if there are no interventions put in place (Nugent, 2008). Concerted efforts by scientists and entrepreneurs in affected countries – northern as well as southern – towards R&D in health biotechnology can play an important role in addressing these health challenges.
Collaboration between developed and developing countries in S&T fields such as health biotechnology can be mutually beneficial to both parties in terms of increasing their ability to innovate. Developing countries such as Brazil, China and India are witnessing strong growth of their economies, including that of their domestic pharmaceutical markets. The growth rate of pharmaceutical markets in the emerging economies is now reportedly higher than that of the developed markets. The Brazilian and Indian pharmaceutical markets are experiencing average annual growth rate of about 10% whereas the Chinese market is growing at about 20% annually (Cavanagh, 2010). In contrast, the US pharmaceutical market is expected to grow at an annual rate of 1-2 % (Business Insights, 2009). As a result, biotechnology and pharmaceutical companies worldwide are showing increased interest in emerging economies markets, and partnerships with local actors can be a key means by which to enter them. Southern firms working in health biotechnology are also interested in forging linkages with northern partners (Melon et al., 2009). Gaining access to strategic knowledge, expertise and resources may be driving these ties.

At this time, scientific knowledge produced in northern countries vastly outstrips that being produced by southern countries. Several scholars have looked at the distribution of scientific publications globally and shown that the majority of the world’s scientific publications are produced by developed nations (Inonu, 2003; OECD, 2010; Schofer, 2004; Wagner et al., 2001). Between the years 1991 and 2002, for example, the top ten publishers of health biotechnology scientific papers in international peer-reviewed journals were all developed countries.
(Thorsteinsdóttir et al., 2006). However, in recent years, the emerging economies Brazil, China and India are investing in building domestic capacity, and their contributions to the world scientific literature in this field are rising. For instance, between 1998 and 2008, China increased its output of scientific articles in general by about twenty-fold (OECD, 2010). It is emerging as one of the world’s main producer of scientific knowledge. Brazil, China and India’s scientific publications in health biotechnology are noted to be growing in recent years (Ferrer et al., 2004; Kumar et al., 2004; Thorsteinsdóttir et al., 2006; Thorsteinsdóttir et al., in press; Zhenzhen et al., 2004). Building domestic capabilities in health biotechnology may help these countries address health challenges faced by their populations. However, collaboration with experienced, knowledgeable northern partners is also regarded to be essential to upgrading and maintaining the domestic skills base (Sagasti, 2004; Velho, 2002). Intensive interactions with world leaders in health biotechnology can boost developing countries’ ability to build indigenous capacity.

1.2 Study objectives and scope

As scientific and technological capacity grows in Brazil, China and India, there appears to be heightened interest among developed countries to pursue collaboration with them, and several countries, including Canada, are entering into formal agreements to promote mutual S&T cooperation (Boekholt et al., 2009). The ISTPP (International Science & Technology Partnerships Program) was announced by the Government of Canada in 2005, to promote collaborative
R&D activities with foreign partners. Although the initiative does not restrict its attention to the emerging economies, it does place a strong focus on them. The five-year, CDN$ 20 million program was established to deepen S&T relations with four select countries – Israel, India, China and Brazil. Renewed funding for ISTPP was announced by Canada in its 2010 federal budget. Biotechnology is an area of focus of the ISTPP (DFAIT website a; ISTPCanada website a).

International S&T cooperation has been assumed by donor agencies and international funding organizations to be positive in and of itself (Gingras et al., 1999; Hatton & Schroeder, 2007). The governments of Canada, Brazil, China and India regard north-south collaboration as leading to mutual economic and health benefits, and are contributing resources towards fostering partnership in S&T. However, up to now, there has been limited investigation into Canada’s collaboration with emerging economies such as Brazil and India in S&T fields. In order to best target public policy to foster such collaboration, it is important to understand more thoroughly the dynamics and processes involved. It is pertinent to know answers to questions regarding how much partnership currently exists between Canada and the emerging economies in S&T fields such as health biotechnology, why scientists and entrepreneurs from the two sides decide to work together, what impediments they face in their partnership, and what are some of the outcomes of collaboration. Understanding the processes of Canada-emerging economies collaboration in health biotechnology can inform public policy in Canada as to how it can best harness gains from S&T partnership with these countries.
'North-south collaboration' in the context of this study refers to partnership between scientists and entrepreneurs residing in developed (‘northern’) countries with counterparts residing in developing (‘southern’) countries involving joint cooperation on a scientific or technological endeavour. By ‘research’ collaboration I mean partnerships involving academics at universities and public research institutions. ‘Entrepreneurial’ collaboration refers to partnerships involving private sector firms. The next section provides greater detail of the main terminology used in this dissertation.

The overall aim of my dissertation is to learn about north-south S&T collaboration by conducting a detailed investigation into Canada’s collaboration – both research and entrepreneurial – with two emerging economies, Brazil and India, in the field of health biotechnology. Specifically, the four main objectives of this study are to:

- map levels and key characteristics of Canada-Brazil and Canada-India research collaboration; map levels, geography and main features of Canada’s entrepreneurial collaboration with developing countries in health biotechnology,
- identify the motivations, challenges and impacts of Canada-Brazil and Canada-India health biotechnology collaboration in order to gain greater understanding of the factors that shape these partnerships,
- advance a conceptual framework to better understand north-south S&T partnerships,
• consider policy implications for how Canada can support health biotechnology collaboration with the emerging economies so that it is likely to result in strengthened innovation.

Brazil and India were chosen as the emerging economies whose cooperation with Canada in health biotechnology is examined in this study. As indicated above, both Brazil and India have shown strengths in health biotechnology in recent years, and by entering into bilateral S&T agreements with Canada, they have indicated interest in cultivating relations with Canada in this respect. China, too, is an emerging economy that is of strategic interest to Canada. However, including Canada-China collaboration in health biotechnology is a substantial undertaking and deemed too large for my dissertation. Other members of the research team are conducting this work.

1.3 Core definitions and terminology

In this section, I define the terminology key to the discussion in this dissertation: ‘collaboration’; classification of nation-states into groupings such as ‘north/south’, ‘developed/developing’, ‘emerging economies’; and ‘health biotechnology’.

1.3.1 Definition of ‘collaboration’

Several scholars have discussed the term ‘collaboration’. Katz and Martin (1997), for example, attempt to define and draw boundaries around the concept of research collaboration in their work. They consider the question of how closely involved a contributor has to be in a research project to earn the title
‘collaborator’; for instance, would an individual who contributed to a few but core tasks be considered on the same plane as someone who contributed to many but relatively minor elements of the project? Katz and Martin go on to suggest specific criteria for who in their opinion would constitute a true collaborator (the original project proposer, the fund raiser, those who make frequent contributions to the project, etc). They, however, point out that there are exceptions to the categories they identify. In this sense, Katz and Martin’s conception of collaborators and collaboration is blurry. Those who do not meet the criteria they propose, but nonetheless have provided important inputs to the research project, may or may not be regarded as collaborators. It can be difficult to apply the criteria Katz and Martin propose when attempting to determine who is a collaborator in a joint project. Their definition can prove to be vague and ultimately restrictive.

Other scholars have suggested giving wider conceptual meaning to the term ‘collaboration’. In her study of academic relationships in the scientific community in biology, Maienschein (1993) bases her definition of collaboration on the concept of co-labouring. According to Maienschein, in collaboration, individuals or groups can work towards a common product, but it is not necessary that they express their goals in the same way. She emphasizes that collaboration should, at the very least, involve coming together to work towards a common purpose, and for participants to accept some basic responsibility for the project. Her conception of collaboration allows considerable inclusiveness in terms of types of participants who may be considered collaborators. Maienschein’s definition of
collaboration is also flexible in terms of the types of projects that collaborators can co-labour on. Unlike Katz and Martin, her notion of collaboration is not restricted to examining only research partnerships, but can be applied to a broader array of projects. This study relies on Maienschein’s definition. Her definition has greater conceptual scope and is able to encompass consideration of research collaboration aimed at producing cutting edge science as well as firm collaboration concentrating on co-development of new-to-the-world innovation or marketing alliances. The terms ‘partnership’, ‘cooperation’, ‘alliances’, ‘linkages’ and ‘ties’ are also used to denote collaboration in this dissertation.

1.3.2 Country classifications

For analytical, operational and political reasons, scholars, government and international agencies have sought to classify countries into categories based on their economic and human development standing. The ‘north-south’ categorization became popular with the publication of the 1980 report by the Independent Commission on International Development Issues, or the Brandt Report. The report suggested that there is a significant divide in standard of living between the global north and the global south, and recommended large resource transfers from the north to the south. The Brandt Report attempted to understand development issues using a number of dimensions, such as poverty, health, housing and education (Brandt, 1980). The Brandt report was updated in 2001, and it measures countries on additional indicators, including technology and corporations, trade, money and finance (Quilligan, 2001). Based on these indicators, the Brandt Line was proposed. It is an imaginary circle at a latitude of
30°N, passing between North and Central America, north of the African continent and India, and lowered to include Australia and New Zealand in the southern hemisphere. The Brandt Line was meant to visually depict the north-south divide. This research examines collaboration between developed and developing countries in the health biotechnology field, and I refer to the north/south classification.

The World Bank’s classification of countries is also used in this work to identify developed and developing countries. It categorizes economies based on gross national income (GNI) per capita (The World Bank website). In this study, the World Bank’s categorizations of high-income countries are referred to as ‘developed countries’, and low and middle-income countries are referred to as ‘developing countries’.

The term ‘emerging economies’ is also used in this research. The emerging economies are a subset of developing countries. First coined in 1981, the term refers to low and middle-income countries that have embarked on economic development and reform programs, have begun to liberalize their domestic markets and are considered to be fast-growing economies (van Agtmael, 2007). Both Brazil and India are considered to be emerging economies (OECD, 2009; Rao, 2008), and I also use this term to refer to these countries in this dissertation.
1.3.3 Definition of ‘health biotechnology’

The focus of this study is on Canada-emerging economies collaboration in the field of health biotechnology. In his research, Pisano (2006, p. 16) defines biotechnology as "the broad range of technologies for drug R&D based on scientific advances in such fields as biology, chemistry, medicine, and computer science." He does not include agricultural or industrial applications of biotechnology in his work. He regards biotechnology as it relates to human health, and confines it to examining biotechnology as it applies to novel drug development. Pisano’s definition of biotechnology is too narrow for the purpose of this dissertation; it does not consider, for instance, development of diagnostics and vaccines, development of health products from indigenous plants or adapting existing products and services for novel settings. These are technologies and activities that are important when thinking about health biotechnology in a context where developing countries are involved (Daar et al, 2002; Thorsteinsdóttir et al., 2004a; Thorsteinsdóttir et al., 2004b).

The OECD, which conducts periodical statistical surveys of biotechnology sectors in its member countries, and more recently of some developing countries, employs a broader definition of biotechnology. The OECD first developed its definition of biotechnology in 1998, and later updated the definition in consultation with eighteen member countries and two non-member countries. The OECD defines biotechnology in the studies it conducts as follows: “the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the
production of knowledge, goods and services” (van Beuzekom & Arundel, 2009, p.9). The OECD also includes a list of techniques as part of its definition of biotechnology, including technologies related to DNA/RNA, proteins and other molecules, cell and tissue culture and engineering, process biotechnology, gene and RNA vectors, and nanobiotechnology (van Beuzekom & Arundel, 2009). For this study, I relied on the OECD’s definition for biotechnology. I, however, restricted my attention to production of biotechnology knowledge, goods and services for the health sector. This covers biotechnology applications in the fields of clinical medicine and biomedical research.

1.4 Structure of the dissertation

The rest of the dissertation is organized in the following way:

**Chapter 2** provides a literature review on the topic of north-south S&T collaboration and its relevance to my research topic. I provide background on historical and policy issues regarding north-south S&T interactions, and outline the literature exploring north-south research as well as entrepreneurial collaboration in S&T. I review what is known about the current state of the pharmaceutical/biotechnology industrial sector as well as global knowledge transfers. I draw attention to the fact that thus far little analysis on north-south S&T collaboration has been performed that takes into consideration the influences of the wider institutional environments in developed and developing countries. I summarize the main gaps in the literature in the last section, and restate the objectives of the dissertation.
Chapter 3 describes the methods used to conduct the study. I discuss why a mixed methods approach involving scientometric analysis, a survey exercise and case study research is appropriate for my study. The chapter describes what data was collected, why, and how. I discuss the techniques used to analyze the evidence collected.

Chapter 4 is the first among three chapters that present the main findings of this project. I present results from surveying Canadian health biotechnology firms to map partnerships they have with collaborators in developing countries. I analyze levels of Canada-developing countries entrepreneurial collaboration, its geographical extent, and its overall characteristics.

Chapters 5 and 6 are concerned with the in-depth findings from case study research on Canada-Brazil and Canada-India health biotechnology collaboration respectively. I report on levels of Canada-Brazil and Canada-India research collaboration in health biotechnology by analyzing their co-authored scientific papers published in international peer-reviewed journals. I discuss the main motivations for scientists and firms to initiate collaborative projects, the challenges encountered and the impacts achieved. I include perspectives from both the Canadian and the emerging economies sides in the discussion.

Chapter 7 discusses the key findings from the three results chapters. Here I summarize the results of the overall study and discuss them with reference to the literature review. I then present a model of north-south collaboration in health biotechnology based on the findings of this study. I consider how the research
findings advance the scholarly literature, and elaborate on implications of the research for public policy in Canada. Finally, I indicate limitations of the research and suggest areas that warrant future investigation.
Chapter 2

Trends in north-south S&T partnerships: a literature review

2.1 Introduction

In this dissertation, I want to look inside the ‘black box’ of Canada-emerging economies health biotechnology collaboration, understand how it works and how it can be shaped. In this chapter I review the literature that is key to the discussion in the remainder of the dissertation.

I begin by describing historical trends in policy measures that have sought to promote S&T interactions between developed and developing countries. I then present what is known about north-south research collaboration – the main motives driving it, the challenges faced by collaborators, and its impacts thus far. Key characteristics of the health biotechnology research landscape in Canada, Brazil and India are described. I cite the limited studies that have examined Canada’s research collaboration in health-related fields with developing countries thus far.

Studies examining north-south inter-firm cooperation are fewer than those available on research collaboration. I identify the literature that has examined main features of the health biotechnology private sectors in Canada, Brazil and India. I also cite studies that have examined Canada-developing countries firm collaboration in S&T fields.
In order to provide context to my research, in this chapter I present some of the debates surrounding the complex relationship between basic and applied research. I discuss what scholars have written about how S&T knowledge is exchanged locally and globally. I describe what has been written about the role of emerging economies firms working in the global pharmaceutical/biotechnology sector at a time when the innovation trajectory in this industry is expected to undergo changes.

Finally, I present conceptual frameworks that scholars are depending on to support critical reflection of north-south S&T collaboration. I consider criticisms of these conceptual tools and argue for the usefulness of the systems of innovation framework in analyzing north-south S&T collaboration.

2.2 Policies guiding north-south S&T collaboration through the ages

Interactions between northern and southern countries in research go back to colonial times. ‘Colonial science’, however, was oriented towards the interest of imperial powers. Building indigenous research capacity in the south was not of concern for colonial governments, and higher education in the south was neglected (Kumar, 1990; Sagasti, 2004; Stepan, 1976).

After World War II, northern governments started to pay attention to promoting research capacity in developing countries to address development challenges in the south. The main mechanism by which they encouraged research activities
was through foreign aid channels. Foreign aid is “a voluntary transfer of public resources, from a government to another independent government, to an NGO, or to an international organization (such as the World Bank or the United Nations Development Programme) with at least a 25% grant element, one goal of which is to better the human condition in the country receiving the aid” (Lancaster, 2007, p.9). ‘Research-for-aid’ programs became part of foreign aid. They were meant to strengthen research activities in the south through flows of financial and technical assistance from the north to the south. Research-for-aid initiatives were prompted by genuine worry of northern donors for the welfare of developing countries, but studies show that in reality foreign aid is influenced by various political and strategic factors (Alesina & Dollar, 2000; Barro & Lee, 2005). Research-for-aid was also an instrument for political swaying during the Cold War; the superpowers and former colonial powers – the US, the USSR, France, the UK – became major donors for encouraging research activities and higher education in the south. History and linguistics are among additional factors that shape research-for-aid programs (Gaillard, 1998; Shinn et al., 1997).

Northern governments’ research-for-aid programs followed a ‘linear’ paradigm where the objective was to find quick solutions to development challenges in the south. According to this linear conception, it was felt that research produced in northern countries could be transferred to the south, and effectively applied to provide solutions to problems faced there. The focus was on mobilizing what was considered to be the ‘best’ scientific research predominantly generated in northern countries to address southern challenges (Gaillard, 1998; Velho, 2002).
However, northern technologies transplanted to the south were not always economically, culturally or socially appropriate for southern settings, and as a result, could be ineffective and lie abandoned (Owusu-Baah, 1995).

Between the late 1950s and the 1970s many southern countries began to gain independence, and the world saw the establishment of multilateral organizations such as the United Nations Development Programme (UNDP), the World Bank, the Development Assistance Committee (DAC) with a mandate geared towards helping southern countries meet their development goals. During this period Australia, some of the Scandinavian countries such as Sweden, and then Canada became significant donors to southern nations (Gaillard, 1998). Canada set up the International Development Research Centre (IDRC) in 1970 as an official institution to promote research for development in southern countries (IDRC, 2010).

The idea of the south becoming self-sufficient in addressing its own development challenges by harnessing S&T was gaining support among northern donors in the 1970s. Donor agencies began to encourage indigenous research capacity development in southern countries such that they were able to counter their own development problems. Sweden’s Sida/SAREC and Canada’s IDRC became proponents of this paradigm; supporting the development of endogenous research capabilities in southern institutions independent of northern directives became their primary goal. These donor agencies provided technical assistance, funding towards institution building as well as support to individual scientists and groups for their training and formation. However, it soon became clear that
maintaining research capacities in southern institutions was more difficult than initially perceived. Donors began to realize that without continuous, close interaction between their and southern researchers, research capacities in southern institutions would deteriorate (Gaillard, 1998; Sagasti, 2004).

By the early 1990s, slow signs of success, aid fatigue, and a shift in world geopolitics with the end of the Cold War led to reconsideration by donor countries of mechanisms by which they supported research activities in the south. Donors began to re-think the foreign aid paradigm with the uneven donor-recipient relationship at its core as the apparatus for stimulating research activities in the south. Northern countries began to emphasize research collaboration with southern counterparts that led to mutual benefits. Replacing the concept of aid with that of mutual gain began to be recognized (Gaillard, 1998). However, despite acknowledgement of the importance of north-south research cooperation to advance mutual interests, partnership between the north and south in this regard has been elusive (Gaillard, 1998; Sagasti, 2004; Velho, 2002).

Scholars argue that one reason for the elusiveness of partnerships is that the programs put in place to promote north-south research collaboration are still planned and operated on the basis of a linear paradigm that primarily supports north to south unidirectional flows of resources and finances, and does not consider the complex realities of southern settings where the initiatives are to be implemented (Bautista et al., 2001; Sagasti, 2004; Velho, 2002). The programs assumed that the ideas and efforts of outsiders could result in significant development in southern countries and did not consider the viewpoints of those
actually concerned. As the initiatives ignored the complex factors that influence north-south research collaboration, they have had limited impacts on development (Velho, 2002).

In recent years, the emerging economies – Brazil, China and India – are becoming intent on putting in place international research cooperation initiatives with northern countries that shift the dynamic from their being passive recipients to their being active, equal partners in the programs. For example, Brazil and India have increased their resource allocation towards promoting S&T cooperation programs with northern partners, including the EU, Japan and the US. China is setting up S&T offices in embassies to promote partnerships with the host countries (Boekholt et al., 2009). Thus, the call for partnership in S&T activities is becoming louder from both the northern and the southern sides. However, little research has looked at how the institutional contexts in the north and in the south interact in the formation of north-south S&T collaboration and in sustaining them.

2.3 North-south research collaboration

Collaboration is considered to be inherent to conducting scientific research. de Solla Price (1963), noting the steep growth of multiple-author scientific papers by researchers published in the field of chemistry, predicted the extinction of single-author papers in science. Recent research suggests that many branches of science seem to be getting close to this point (Abt, 2007). Indeed scholars have conceived the very spirit of science as being collaborative in nature; the
international scientific community may be considered to be one large collaborative where all scientists exchange information, discuss ideas, and work together to advance scientific knowledge (Katz & Martin, 1997; Kneller, 1978; Merton, 1973; Polanyi, 1963). Scientists react to the intellectual environment created by their peers in pursuing their own research aims. The scientific knowledge base develops when researchers extend the work of predecessors and peers with their own contributions. The scrutiny, review and evaluation of new research by the scientific community is what gives the scientific knowledge base its reliability. Scientists test the findings of their peers, check its validity and rely on work that has been judged to be accurate as the basis for furthering their own research. They also seek advice and assistance from peers to determine how to relate their findings to other areas of research. Thus, science grows as a result of dialogue, interaction and collaboration between members of the wider scientific community.

It is important for researchers in developing countries to be engaged in scientific activities abroad. Sagasti (2004) observes that collaboration with the international scientific community is a critical means by which southern scientists can build their endogenous S&T capabilities. Without sustained and intensive interactions with leading knowledge producers in S&T fields, it can be difficult to maintain the local capacity that has already been built. Research communities that lack connections to mature scientific networks run the risk of their science base stagnating. However, developing countries whose scientific communities are still working to build research capacity and to define niche areas of scientific
strengths may be vulnerable to being isolated from global scientific networks because they may face difficulty in attracting the attention of global scientific leaders.

Reviewing the literature reveals that studies have examined different facets of north-south research collaboration. But studies on research collaboration between northern scientists are far more extensive (Bukvova, 2010). Bradley (2007) notes that the body of work on north-south research collaboration is of particular value to donor agencies interested in the potential of these partnerships to contribute towards poverty alleviation and meeting development goals in the south. The literature on north-south research collaborative efforts is diverse; for example, it covers many different scholarly disciplines, including research in agriculture, social sciences and health. Studies on north-south research collaboration aimed at addressing development challenges have looked at aspirations of researchers to enter into partnerships, barriers encountered and outcomes achieved. I discuss these studies below.

2.3.1 Motives driving north-south research collaboration

Studies on international research collaboration suggest the ability to access financial resources, expertise, and research materials are among the main motives propelling partnership. I consider these in turn below.

For developing countries’ scientists, entering into north-south research partnerships may be a means to access funding to further their research objectives. This motivation also applies to scientists from northern countries who
work with each other to pool resources, share research costs and access financing (Beaver, 2001; Heinze & Kuhlmann, 2008). But this tendency can be even stronger in the case of developing countries researchers. Research conditions in southern universities and research institutions can be deficient; they can lack specialized instrumentation and equipment, their libraries can be poorly supplied, they can have only limited access to electronic and online resources (Gaillard, 1994; TWAS, 2004). By entering into research collaboration with developed countries’ scientists who do not experience these shortcomings, researchers from developing countries may have the opportunity to continue their scientific explorations.

North-south research collaboration may also be attributed to the need to access specialized scientific expertise. For complicated research issues with multiple dimensions, a team of experts is more likely to be successful than any single researcher in trying to tackle the research problem. For application-oriented research problems, there are many factors and complex interactions to take into consideration, and such tasks cannot be handled by any single academic disciplines (Gibbons et al., 1994). Scholars who have studied research collaboration among northern scientists place emphasis on access to expertise as a main motivation for research collaboration (Birnholtz, 2007; Katz & Martin, 1997). In order to address complex research problems, it is useful to gain from the contributions of scientists having different types of expertise. Combining specialists’ knowledge can lead to an outcome that is greater than the sum of the parts. It can increase creativity in problem solving.
Developing countries can face difficulty in being able to locate the necessary expertise within their borders. In developing countries, there may be a few scientists working in highly specialized subfields. As indicated in chapter 1, several studies have presented evidence for the disparity in scientific output between developing and developed countries (Gibbs, 1995; Inonu, 2003; May, 1997; OECD, 2010; Schofer, 2004; Wagner, 2001). In 2001, for instance, UNESCO reported that developed countries, particularly in North America and Europe, accounted for approximately 88% of all scientific publications in the Science Citation Index (SCI) database (UNESCO, 2001). Due to the small size of their indigenous scientific communities, southern scientists can be isolated in their efforts. In order to compensate for local weaknesses and access the relevant expertise, developing countries may have little choice but to reach out internationally to seek collaborators.

Northern research teams can enter into partnerships with scientists in the south to access unique research material – for example, geographic sites, plant life, human population groups – that can only be found in southern countries. They seek help from southern counterparts to perform field studies and to benefit from local knowledge (Hurtado & Salzano, 2004). Examples of research fields where unique local research material or sites in developing countries attract the interest of developed countries researchers include seismology, geodynamics, botany and biology (Wagner et al., 2001). Tapping into the biodiversity in the south is particularly important for research in the pharmaceutical/biotechnology sector. Bound by the Tropic of Cancer in the northern hemisphere and the Tropic of
Capricorn in the southern hemisphere, the tropical zone of the earth contains the greatest wealth of the world’s flora and fauna. Many developing countries are located in this geographic zone. Botanists suggest that at least 7,000 of the most commonly used drugs in modern medicine have been derived from plants originating from the tropical regions of the globe (The Crucible Group, 1994). Pharmaceutical companies collect samples from swamps, streams and soils in biologically rich geographic locations. Compounds extracted from these samples are stored in libraries, and these are paramount in the screening and searching for novel drug candidates (Henderson et al., 1999). Developing countries may possess small, isolated populations with unique genetic characteristics valuable for research in genomics. Studying these special populations can yield important information about genetic susceptibility to illness, potential adverse drug reactions, and clues towards new therapies (Salzano, 2004). Northern researchers might rely on partnerships with scientists from southern institutions to help them navigate the local environment in order to access indigenous biodiversity. Biopiracy, however, is a potential risk of research involving such bioprospecting projects (Merson, 2000). ‘Biopiracy’ is a term that describes situations where indigenous knowledge of nature is exploited for commercial gain, but with no compensation to the indigenous peoples themselves. The Convention on Biological Diversity (CBD), which came into effect in 1993, aims to enable developing countries better benefit from their traditional knowledge and natural resources. However, some countries such as the US have not ratified the CBD. Another issue is that governments, which have signed the agreement, fail
to pass laws implementing provisions of the CBD (Convention on Biological Diversity website).

I have reviewed the literature on possible motivations for scientists from the north and from the south to engage in research collaboration with each other. However, this may not tell the whole story. These motivations are speculations based on looking at the characteristics of science systems and research conditions in the north and in the south. Although scholars such as Castillo (1997), Maina-Ahlberg et al. (1997) and Cohen (2000) have elicited northern and southern scientists’ perspectives regarding north-south research partnerships, empirical work where southern and northern scientists are asked directly about their reasons for entering into research collaboration with each other is limited. Finally, the varying emphasis scientists place on the various motivations in north-south research collaboration is unknown.

2.3.2 Challenges encountered in north-south research collaboration

Scholars have written about challenges faced in north-south research collaboration, particularly with regards to the politics and ethics of these international partnerships. Here I review the literature that discusses the main challenges of research collaboration between developed and developing countries partners.

A major concern expressed in the literature relates to inequalities in north-south research relationships, and how these can negatively impact the partnership at all stages of the research – from creation of partnerships and agenda setting to
project management and budget administration, and finally implementation and evaluation of the project (Gaillard, 1994; Jentsch & Pilley, 2003; Maselli et al., 2006). According to Gaillard (1994), asymmetry between northern and southern research partners and the dominance of northern partners are at the root of the main problems found in north-south research collaboration programs. The inequalities stem from their differential access to information, training, funding, ability to attend conferences and publishing opportunities. Jentsch and Pilley (2003) observe that these inequalities impede north-south collaborative projects even when partners report similar values with regards to conceptions of equality and mutual respect. The asymmetries translate into imbalances in division of labour in collaborative projects; researchers from the north are responsible for conception tasks (formulating research questions, research design, etc) whereas their southern colleagues are relegated to execution tasks (data collection, running experiments, etc). Due to these imbalances, outcomes reaped by northern and southern partners from the same collaborative research projects end up skewed; northern partners publish more and are more likely to present findings at conferences than their southern counterparts (Gaillard, 1998).

Scholars have expressed concern about the continuing effects of neocolonialism in north-south research partnerships. According to such a view, for developing countries to achieve development goals, it was necessary for them to adopt Western values and knowledge while disregarding the specific historical, economic, social and cultural situation they faced. Costello and Zumla (2000) claim that most of medical research projects in developing countries that are led
by northern teams are ‘seemolonial’ in nature. The authors point out characteristics of projects that follow a semicolonial model – these are dominated by northern members of the project, and have only few links to southern institutions. As a result, Costello and Zumla argue the projects are not sustainable in the local setting, and they cannot lead to positive impacts on developing countries. A 1996 editorial in the journal *Lancet* discusses the field of tropical medicine and observes that it is necessary to move away from colonialist mentalities and “old-fashioned paternalism” (p. 629) in relationships between northern and southern academic institutions. Otherwise there lie significant risks in sidelining health priorities of the south in favour of meeting northern-led agendas. Rakowski (1993) adds to the discussion from the vantage point of North American sociologists who work on developing countries issues and form collaborations with local colleagues. She contends that sociologists receive little guidance from institutional ethics codes on how to overcome neocolonial notions.

Scholars note that by being involved in north-south collaborations southern researchers risk working on projects that are of interest to their northern partners, but which lack relevance to local challenges faced in their own regions. There is the danger of north-south partnerships diverting the attention of southern researchers away from domestic priorities towards northern backed projects that are supported by significant financial incentives, and are prestigious (Sagasti, 2004). The argument is also made that internationally oriented research can overcome the isolation developing countries scientific communities face. In choosing to work on research questions that scientific leaders in the north are
trying to address, southern researchers can stand to gain from scientific and technical assistance, information sharing, and ultimately capacity building which can enable them to confront their own local issues in the future (Stolte-Heiskanen, 1987). Still with such a strategy it can be a relatively long time until impacts are achieved in the south, if at all. There is possibly a range of intermediate approaches whereby southern researchers can balance national versus international emphases of their research initiatives. But determining this balance can be tricky; it likely involves trade-offs and making difficult choices (Sagasti, 2004). It is questionable to what degree critical stakeholders in the developing countries are involved in debating these issues and priority setting (Gaillard, 1998).

As discussed above, there exists considerable literature on the challenges faced in north-south research collaboration. These focus predominantly on inequalities between northern and southern scientists, and the problems resulting from these asymmetries. Neocolonial tensions are cited as a contributor to challenges encountered. This may, however, not have much relevance to Canada’s collaboration with southern partners. Canada was never a colonial power, and boasts a highly multicultural society. The literature also concentrates on challenges faced by southern partners in north-south research partnerships. There is less known about challenges researchers from northern countries face when working with southern counterparts from the emerging economies. These are areas that warrant deeper investigation.
2.3.3 Outcomes of north-south research collaboration

Previous studies have considered the outcomes of north-south research collaboration. North-south collaboration is credited to have improved research capacity in southern countries. However, its impact with regards to achieving innovation in developing countries is viewed with skepticism.

A number of northern institutions have commissioned studies to examine the impact of research collaboration in development projects. Among these include AUCC (Association of Universities and Colleges of Canada), RAWOO (Netherlands Development Assistance Research Council) and KFPE (Swiss Commission for Research Partnerships with Developing Countries). Theirs as well as other studies have credited donor programs as playing a major role in improving research capacity in southern universities and research institutions. The programs have led to strengthening research undertaken at southern institutions, improving the quality of graduate level education, and increasing the numbers of researchers trained (AUCC, 2006; Bautista et al., 2001; KFPE, 2005; RAWOO, 2001; Velho, 2002).

Scholars have examined impacts of internationally collaborative research (north-north as well as north-south). Narin et al. (1991), analyzing data primarily involving European countries, report that scientific publications that have international co-authors have higher citation impacts than publications that are not internationally coauthored. According to a study by Arunachalam and Doss (2000) that examined Israel's publication record in biochemistry and biophysics,
internationally coauthored papers are published in higher impact journals than papers that are not authored in international collaboration. Sooryamoorthy and Shrum (2007) surveyed scientists in South African universities and research institutions, and their study found only little evidence that international collaboration is related to publication productivity. However, complex factors can play a role in influencing productivity from international collaboration, including the level of scientific and technological capacity already present in the country, to what degree the national scientific community is open to international collaboration in the first place, the criteria put in place by universities, research institutions and funding agencies for researchers’ career advancement. Oldham (2005) takes a broader view of impacts resulting from north-south research collaboration, and points to the potential benefits to developing countries in terms of the partnerships opening channels for knowledge and experience exchange, providing access to scientific facilities and ultimately resulting in capacity building in research related activities. To be able to measure these types of outcomes, it is necessary to widen conceptions of impact and effectiveness of collaborations. Study methodologies that include case study research in addition to scientometric analyses can be useful to capture such effects.

Concern is expressed that donor-led programs promoting north-south research cooperation lack linkages to wider stakeholders in local communities in the south – for example, domestic businesses – and, as a result, have only had limited impact on stimulating innovation (Velho, 2002). Innovation is considered to be a key factor for sustainable economic development (Lundvall et al., 2010). By
examining the case of Canada-emerging economies collaboration in health biotechnology, the research in this dissertation aims to better understand the potential of north-south research collaboration to result in increased innovation for both sides.

2.4 Canada-emerging economies research collaboration in health biotechnology

2.4.1 Features of the health biotechnology research scene in Canada, Brazil and India

In recent years, the emerging economies have been showing significant indigenous growth in fields such as health biotechnology. For instance, Brazil's standing in terms of number of health biotechnology papers published in international peer-reviewed journals went from 20th place in 1998-2001 to 14th place in 2006-2009. China's world ranking went from 8th place in 1998-2001 to 2nd place in 2006-2009 (Thorsteinsdóttir et al., in press). These trends suggest that with emerging economies making strong contributions to the field, the landscape of research in health biotechnology is changing.

The domestic capabilities being developed by emerging economies can facilitate their entry into international scientific networks. Scientific capacity development in emerging economies may be of interest to northern countries such as Canada because it presents opportunities for scientific partnership. In forming ties to burgeoning scientific communities in the emerging economies, Canadian
scientists can access new knowledge that enables them to extend their own research in novel ways.

Canada is a country that has built significant strengths in health biotechnology research over the years. The Canadian government has prioritized supporting research in this field since it first emerged in the 1980s. The National Research Council (NRC) set up public laboratories, including the Biotechnology Research Institute in Montreal and the Institute of Biological Sciences in Ottawa, to nurture health technology research (Niosi & Bas, 2004; Science-Metrix, 2005a). Canadian funding agencies such as Genome Canada have allocated generous funding support to genomics and proteomics based research (Genome Canada website). Federal and provincial governments have supported health biotechnology research projects at Canadian universities. Universities in Canada that have a strong record in life sciences research include the University of British Columbia, McGill University and University of Toronto in the metropolitan cities of Vancouver, Montreal and Toronto respectively (Niosi & Bas, 2001). Canadian scientists rank among the top ten in the world in terms of number of health biotechnology scientific papers published in international peer reviewed journals (Thorsteinsdóttir et al., 2006).

Although Canada’s investment in health biotechnology over the years has enabled it to achieve a strong position in the field globally, it is uncertain how well it will be able to hold on to this status, particularly as novel players begin to enter the field. For example, in 1996, Canada was in 6th place globally in terms of number of health biotechnology publications, but by 2010 it had slipped to 8th
place (Thorsteinsdóttir et al., in press). As mentioned earlier, research collaboration with growing knowledge producers in the field may prove to be an avenue by which Canada can continue to maintain its global competitiveness in health biotechnology.

As described above, the emerging economies are increasingly active in health biotechnology. The Brazilian government initiated programs to encourage biotechnology development in the country from the 1970s onwards. Past political and macroeconomic instability meant that biotechnology development received only intermittent support in the 1970s and 1980s. The situation has improved since. Currently domestic biotechnology R&D initiatives are funded by federal and state agencies. Brazil’s Conselho Nacional de Desenvolvimento Científico e Tecnológico or National Council on Scientific and Technological Development (CNPq) and the state level foundations for the promotion of scientific research (FAPs) play an important role in promoting biotechnology development in the country. Brazilian research institutions and universities are productive in health biotechnology research. Fundação Oswaldo Cruz (FIOCRUZ) in Rio de Janeiro is a Brazilian public research institution that is affiliated with the Ministry of Health. Not only does FIOCRUZ conduct basic research in health biotechnology, it has a strong mandate in addressing public health challenges in Brazil. The University of Sao Paulo (Sao Paulo, Brazil), the Federal University of Rio de Janeiro (Rio de Janeiro, Brazil), and the Federal University of Minas Gerais (Belo Horizonte, Brazil) are among the most active producers of health biotechnology papers in international peer-reviewed journals in the country. In addition to public
research institutions and universities being active in health biotechnology research, Brazil is home to international non-profit research organizations such as the Ludwig Institute (Sao Paulo, Brazil), which is dedicated to cancer research (Ferrer et al., 2004).

I now turn to the Indian scene. India first identified biotechnology as a means to address its development goals in health and agriculture in its sixth Five Year Plan (1980-85). The Department of Biotechnology (DBT) was specifically created at the national level to administer funds to encourage research in this field, and also to guide policy in this area. Other Indian federal government agencies involved in providing financial, infrastructure and policy support for health biotechnology research include the Council for Scientific and Industrial Research (CSIR) and the Indian Council of Medical Research (ICMR). The CSIR has a network of laboratories and research institutions located throughout India, a number of which are engaged in application of biotechnology techniques to drug discovery and diagnostic development. The Centre for Cellular and Molecular Biology (Hyderabad, India) and the Indian Institute of Science (Bangalore, India) are among the public research institutions that actively publish scientific papers in health biotechnology in international peer-reviewed journals (Kumar et al., 2004).

2.4.2 Examining Canada-emerging economies research collaboration in health biotechnology

There has been limited investigation into measuring levels of Canada-India and Canada-Brazil research collaboration in health biotechnology. I discuss some
scientometric studies here that have looked at Canada’s co-authorships with
developing countries in the life sciences in general, and identify areas that would
benefit from further research. Scientometric studies utilize quantitative analysis to
examine patterns of scholarly articles publication within a scientific field.
Examining levels of co-publications is regarded to be a proxy for measuring
research collaboration.

Science-Metrix (Montreal, Canada) conducted a study to map research
collaboration between Canadian and Indian scientists using scientometric
methods (Science-Metrix, 2003). Their scientometric analysis involved examining
scientific papers co-authored by researchers in Canada and India from the SCI
Expanded database in the period from 1990 to 2001. The report examined
Canada-India collaboration in several scientific fields including biology,
biomedical research, clinical medicine, engineering & technology, mathematics,
physics. It did not look at Canada-India co-publications in health biotechnology.

In 2005, Science-Metrix released another report where it examined scholarly
papers in a number of scientific fields co-authored by researchers in Canada and
select seventeen developing countries from the SCI Expanded database in the
1992-2003 period. Brazil and India were among the developing countries
selected for this study (Science-Metrix, 2005b). The findings of this study
suggested that Canada has the potential to build scientific cooperation with Brazil
and India in certain scientific fields. However, the research did not look at
collaboration in the field of health biotechnology specifically, and could not
comment on the prospects of Canadian researchers to work with Brazilian and
Indian peers in this area. Furthermore, the data set Science-Metrix analyzed measures research collaboration between Canada and the two emerging economies up to the early 2000s. It is not recent.

A scientometric study by Thorsteinsdóttir et al. (2006), conducted in collaboration with Science-Metrix, measured levels of north-south co-publishing in health biotechnology by scientists from six developing countries. The study identified co-authored papers published in international peer reviewed literature in the 1991-2002 period and included a focus on Brazil and India. The authors measured the extent of co-authorships the six developing countries have with seventeen developed nations, including Canada. But they do not break down the data on a yearly basis. As a result, the study does not provide understanding of trends in health biotechnology co-publishing over time. Thus, it is limited in its ability to permit contemplation on the potential of Canada’s research collaboration with the two emerging economies in health biotechnology.

2.5 North-south entrepreneurial collaboration

In this section, I explore what the literature reveals about north-south collaboration involving firms. To provide context to the discussion in this dissertation, I sketch what is known about the relationship between collaboration and innovation, discuss the innovation trajectory that has dominated the global pharmaceutical/biotechnology industry, and consider the links between basic research and innovation.
2.5.1 Innovation as a collaborative process

Collaboration among diverse parties is important not only to conduct scientific research, but also to catalyze innovation. Several scholars have defined innovation. Nelson (1993) confined his definition mainly to refer to technical innovation, the bias here being towards high technology industries. Lundvall (1992) views innovation more broadly, and includes organizational and institutional changes, which he considers to be critical in transforming technical innovation into economic results. But these scholars converge in their thinking in that innovation includes not only the introduction of a new product or process, but also its diffusion in the market. Fagerberg (2005) contrasts innovation with invention. He writes:

“Invention is the first occurrence of an idea for a new product or process, while innovation is the first attempt to carry it out into practice…. While inventions may be carried out anywhere, for example in universities, innovations occur mostly in firms, though they may also occur in other types of organizations, such as public hospitals. To be able to turn an invention into an innovation, a firm normally needs to combine several different types of knowledge, capabilities, skills and resources.” (Fagerberg, 2005, p.4-5).

Lundvall (1992) stresses interactive relations and learning as being central to the innovation process; innovation does not occur with economic agents such as firms working alone, but rather it derives from their intense interactions with other organizations to exchange information, knowledge and resources. Johnson
(1992) points out that interactions between dissimilar groups may be key to stimulating creativity; creative processes may be charged by synergies between organizations with varying knowledge, values and goals. Similar to Johnson, Fagerberg (2005) emphasizes the importance of diversity for innovation. He notes that interaction with external sources by individual firms or economic systems can enable greater ability to attain a variety of novel ideas, capabilities, skills and resources, and greater scope to combine these in new, complex, sophisticated ways, thereby enhancing innovation.

For firms in developing countries, linkages with counterparts in developed countries who are technically skilled and have strong business capabilities is important. Collaboration can provide opportunities for knowledge diffusion to compensate for domestic insufficiencies and upgrade skills (Ernst, 2002). For firms in developed countries looking for specialized expertise to further their R&D goals, these may increasingly be found in emerging economies as they develop strengths in S&T.

2.5.2 Innovation in the life sciences sector

Technological innovation in the life sciences sector has been strongly influenced by multinational pharmaceutical companies. Multinational pharmaceutical companies, which can trace their roots to the mid-19th century, have emphasized development of health products with potential blockbuster markets – that is, sales of over a billion dollars. A strong past innovation record based primarily on small chemical molecules, accumulation of knowledge regarding regulatory processes,
and experience with sales and marketing enabled these multinational companies or ‘big pharma’ to exert a dominant force in life sciences innovation (Achilladelis & Antonakis, 2001; Henderson et al., 1999).

When biotechnology emerged, there was speculation that firms in this field with their new, powerful technological base would challenge the dominance of multinational pharmaceutical companies and eventually displace the incumbents. The biotechnology sector is characterized by small firms formed around core technological platforms developed from scientific research spun off from universities and public research institutions (Henderson et al., 1999; Pisano, 2006). The Canadian life sciences sector is interesting in that it is mainly characterized by small biotechnology firms, many of which are spin-offs (Niosi, 2003; Tapon et al., 2001). However, biotechnology firms have not been a force of creative destruction. Rather, over the years, biotechnology firms and multinational pharmaceutical companies developed a co-dependent, symbiotic relationship. Pharmaceutical majors view biotechnology firms as a source of potential innovation. They have sought to boost their product pipelines by forming licensing agreements with biotechnology firms or by acquiring them. Small biotechnology firms, on the other hand, rely on the substantial financial and human resources of big pharma to conduct large, late phase clinical trials, file regulatory papers with national drug authorities, and market internationally (Henderson et al., 1999; Pisano, 2006; Tait, 2007).

In recent years, big pharma has been experiencing challenges (Pisano, 2006; Tait, 2007). Product pipelines are faltering as the most profitable therapeutic
agents that could be derived from screening methods have already been
developed (Tait, 2007). Best-selling drugs are losing their patent protection; more
than three dozen blockbusters will face patent expiry by the year 2012 (Ernst &
Young, 2008). Profit margins of pharmaceutical companies are declining even as
cost of drug development has quintupled since the 1980s (Milne, 2008).
Furthermore, meeting regulatory requirements is becoming increasingly difficult
(Tait, 2007). Multinational pharmaceutical companies are responding to these
stresses by undergoing corporate changes; mergers and acquisitions among
these firms are a strategy by which to replete product pipelines. However, the
massive changes and shifts taking place in the pharmaceutical industry can
result in disruptions to product development endeavours in this sector, including
initiatives being undertaken by biotechnology firms (Pisano, 2006). According to
industry reports, Canadian biotechnology firms have been witnessing a decline
not only due to financing difficulties posed by the global recession, but also as a
result of the challenges being faced by the pharmaceutical sector at large (Ernst
& Young, 2008; Ernst & Young, 2009).

2.5.3 Role of emerging economies firms in the transitioning global
pharmaceutical sector

With emerging economies firms building strengths in the pharmaceutical and
health biotechnology sector (Frew et al., 2007; Rezaie et al., 2008), firms in the
north can increasingly consider alliances with them as part of their innovation
strategy. Alliances in general are a critical strategic tool in biotechnology.
According to Pisano (2006), firms in this sector that are involved in many
partnership deals are viewed to be successful. The business of biotechnology is driven by specialization, and as a result, collaboration is a hallmark feature of this industry.

Due to the increasingly growing, complex and specialized knowledge base in biotechnology, firms in this sector reach out to firms that are geographically dispersed (Powell et al., 1996). Alliances enable biotechnology firms to access complementary resources, which may ultimately enable both parties to create competitive advantage (Baum et al., 2000). Activities in this sector are marked by high costs and high risks, and partnerships is a means by which biotechnology firms can share costs and mitigate risks (Pisano, 2006; Tyler & Steensma, 1995).

Although scholars have looked at collaboration in the biotechnology industry, their focus has mainly been on partnerships involving domestic actors in northern countries. The literature pays scant attention to north-south entrepreneurial collaboration in biotechnology.

Buctuanon (2001) provided empirical evidence that biotechnology firms are globalizing. She showed that firms in the ‘triad’ – the US, Europe and Japan – dramatically increased the formation of joint ventures; since the late 1990s levels of their co-development and collaboration agreements with international partners have grown. However, according to Buctuanon, the preferred locations for these alliances were mostly within the triad, and developing countries were largely left out of these networks.
More recent research on developing countries’ health biotechnology private sectors suggests that their firms are forming linkages with northern partners. Melon et al. (2009) show that the emerging economies are indeed globalizing by entering into collaboration with partners in the north. According to the results of a survey administered by the authors to health biotechnology firms in six developing countries, over half of the respondents reported collaboration with partners in developed countries. About 70% of Indian firms, 60% of Brazilian firms and 30% of Chinese firm respondents cited having linkages with northern collaborators. However, it is not clear to what degree northern firms are themselves globalizing to include developing countries and emerging economies partners in their business strategies.

While multinational pharmaceutical companies are encountering problems of maturity, firms in the emerging economies working in the pharmaceutical/biotechnology space are being presented with new opportunities for growth. By highlighting the case of the Indian sector, Chataway et al. (2007) argue that emerging economies firms have chances to both support and challenge global drug innovation. Emerging economies’ provision of cost-effective R&D may be increasingly lucrative for northern firms looking to reduce expenses and maintain competitiveness. On the other hand, their entry into novel product development initiatives may be a means by which to catch up to northern companies. Some of the novel drug discovery endeavours of Indian firms, for example, may prove to be an additional source to fill the faltering product pipelines of northern firms. Chataway and colleagues go on to suggest formation
of network coalitions between northern and southern firms as a way to produce new health products.

Mytelka (2001) claims to be observing the emergence of international R&D network coalitions in high technology industrial sectors, including in the pharmaceutical sector. Inter-firm collaboration forms the building blocks of the networked business model. Mytelka describes characteristics of such networks. First, knowledge production and sharing between firms in the network is central to the coalition’s activities. Secondly, firms provide their collaborators within the network key complementary assets that contribute to product development. Thirdly, firms expend significant effort to build and sustain trusting relationships as these are key to transfer tacit knowledge between collaborators in the network. In her discussion, Mytelka argues that such organizational forms emerge in industries that are undergoing radical change, and that these are particularly advantageous for strengthening the innovation potential for small and medium sized firms. Working in a network can allow small firms to achieve critical mass and yet afford considerable flexibility. Participation in R&D network coalitions enables firms to widen access to novel markets and new knowledge.

Chataway et al. (2007) mention the potential of network coalitions involving southern and northern partners in the biotechnology/pharmaceutical sector as an alternative to the traditional innovation model of multinational pharmaceutical companies in bringing health products and services to patient populations worldwide. But there has been little analysis performed on this phenomenon.
2.5.4 Role of collaborative research in north-south joint innovation

As discussed previously, this dissertation aims to empirically study Canada-emerging economies collaboration in health biotechnology. It seeks to examine both north-south research as well as entrepreneurial collaboration. The relationship between these two forms of partnerships is also of relevance to public policy. Can supporting only research collaboration lead to joint innovation? Or should governments interested in improving commercial ties in high technology sectors mainly focus on encouraging inter-firm linkages? To begin thinking about these questions, I briefly review the literature looking at the relationship between science and technology, and the economic benefits of conducting basic research. Then, in order to gain greater understanding of the implications of scientific research beyond the local context, I look at mechanisms scholars have proposed by which scientific knowledge crosses national borders.

‘Science’ or basic research seeks to expand fundamental understanding of natural phenomena, whereas ‘technology’ relates to achieving practical objectives for economic gain. The relationship between science and technology is complex. Gibbons et al. (1994) argue that knowledge production is changing from ‘mode 1’ to ‘mode 2’. Mode 1 refers to academic, discipline-based knowledge production, whereas mode 2 refers to research conducted in the context of social or economic application. Mode 2 knowledge creation is characterized by greater transdisciplinarity and collaboration. In this mode of knowledge production, the line between basic and applied research is
increasingly blurry, if not irrelevant. Nelson (2004) also highlights that, in reality, the line between science and technology is far from being distinct, and the two are intertwined.

The relationship between basic research and the innovation process is complex; connections between them are not linear, but rather they are interactive and multidirectional. Publicly funded scientific research is considered to expand the pool of knowledge and technological opportunities that firms can draw from in carrying out their activities (Klevorick et al., 1995; Nelson & Rosenberg, 1994). Working on applied problems can also lead to furthering of basic scientific knowledge. Rosenberg (1990) presents examples of how Louis Pasteur’s work in the wine industry led to the development of the germ theory of disease. Thus, scholars show that basic research and applied research have strong interplay between them, and it is difficult to distinguish between them in practice.

Nelson (2004) argues that in recent years the scientific commons is under threat of erosion as it faces increasing pressure to contribute to practical results. According to him, the science system is mistakenly considered by policymakers to be an untapped source of new, useful knowledge that can be directly taken up by firms and applied. He warns that the science system should not be viewed to be simply a reservoir of commercializable knowledge, and the various non-linear channels through which it contributes to the economy should not be ignored. In his discussion, Nelson notes that the frequent input of basic research into industry was problem solving in projects, rather than prototype technologies that may be commercialized. Without understanding of the complicated nature of the
link between science and technology, there is the danger of crafting ineffective policies and overlooking the considerable indirect socioeconomic contributions of the science system.

Salter and Martin (2001) have sought to map some of the channels by which public investment in basic research can lead to socioeconomic benefits. Basic research is important for expanding the stock of useful knowledge available to firms. Firms, however, have to invest in their own internal research capacity or ‘absorptive capacity’ in order to best benefit from publicly funded basic research (Cohen & Levinthal, 1989). Skilled graduates, who are trained in the science system and enter industry equipped with the ability to solve complex technological problems, are another significant outcome. Novel methodologies and research tools are key outputs of basic scientific research. Developed to grapple with problems in the laboratory, they may be useful for industry. These may be of greater relevance to some industrial sectors more than others. For instance, the pharmaceutical/biotechnology industry, in particular, is noted to benefit from new instrumentation emerging from basic research (Arundel et al., 1995). Firms may be created around research generated from basic scientific exploration. Researchers and students can form spin-off firms around new ideas and technologies developed from conducting basic research. Many biotechnology firms are spin-offs from research-intensive universities. In Canada, it is estimated that about half of specialized biotechnology firms have spun off of university research (Niosi & Bas, 2003). Salter and Martin also point to the role of publicly funded basic research to stimulate social interaction and networking.
Scholarly publications, conferences, consulting contracts, sabbaticals are among the different means of interaction whereby the science system and industry can learn about each other’s activities.

Although they primarily analyze the contributions made by publicly funded basic research to economic growth, the aim of Salter and Martin’s work is to show that the patterns of linkages between the science system and the innovation process are complex and operate through multiple channels. Their research suggests that the knowledge and expertise developed in conducting basic research is not just a source for commercializable technologies, but rather useful for firms to better understand emerging technologies and complete new projects.

Salter and Martin stress face-to-face interaction as being essential for exchange of knowledge, particularly tacit knowledge. Tacit knowledge refers to the skills, experience and insight that individuals gain over the course of their work, but they themselves cannot articulate this knowledge explicitly or fully (Senker, 1993). Potential users can only make sense of scientific knowledge and use it if they are able to access its tacit dimension, which is person-embodied. Firms, for instance, seek direct communication and personal contact with researchers from the science system in order to access their tacit knowledge. Faulkner and Senker (1995) underscore personal interaction as being essential for conveying the tacit expertise necessary to effectively use codified scientific knowledge. The authors discuss that tacit knowledge is better transferred by informal collegial discussions and interactions; absence of friendly relations between parties can hinder transmitting the tacit element of scientific knowledge. Faulkner and Senker
emphasize that informal channels can be better at transferring tacit knowledge rather than formal arrangements.

Given that knowledge flows and transfer depend upon personal contacts and relationships, Salter and Martin (2001) argue the significance of geographical proximity between knowledge creators and knowledge users for facilitation of these processes. Other scholars, however, suggest that challenges of distance may be overcome to access unique knowledge or expertise. Cooke (2005) describes how differential knowledge endowments between bioregions provide the impetus for global linkages in the biotechnology sector (‘Globalisation 2’). Furman and MacGarvie (2009) attest to the importance of proximity with local academic institutions to the growth of an industrial sector. They show this in their study of the historical development of the US pharmaceutical industry. However, they note that for particularly complex or extraordinary projects, firms can find it necessary to reach out to collaborators in geographically distant or even international science systems. Accessing knowledge produced by external sources, in addition to relying on local resources, can be critical for firms’ growth.

Bathelt et al. (2004) consider in their work channels by which codified and tacit knowledge may be exchanged globally. They suggest communication conduits in strategic partnerships, referred to as ‘pipelines’, transfer knowledge across borders. The authors point to several barriers that can impede the functioning of global pipelines, including differences in interpretive schemes, institutional environments, and operating standards across jurisdictions. However, they note that links to external knowledge sources and markets can increase the dynamism
of clusters and prevent them from stagnating. They regard building a strong
degree of trust in long-distance pipeline relationships to be key in maintaining
knowledge flows.

Universities are observed to play a critical part in facilitating global knowledge
flows (Gertler & Vinodrai, 2005). Universities create a social environment that is
open to diverse ideas and viewpoints, and fosters dialogue and debate. Cross-
border movement of faculty and students brings new forms of knowledge to the
university. It also provides entry into research and business networks in
international settings. Formal and informal networks between universities and the
local business community can enable firms to tap into these global knowledge
transfers (Bramwell & Wolfe, 2008).

The literature review reveals that scholars have considered the mechanisms and
processes involved in long-distance scientific relationships, and how local
industry can benefit from these activities. The literature provides context with
which to dissect how north-south research collaboration can contribute to joint
innovation.

2.6 Canada-emerging economies entrepreneurial
collaboration in health biotechnology

2.6.1 Features of the health biotechnology domestic private sector in
Canada, Brazil and India
I now focus my attention on health biotechnology firms in Canada, Brazil and India. In this section, I review some of the main features of the Canadian, Brazilian and Indian health biotechnology sectors, and consider how these characteristics can lead their firms to seek out north-south partnerships.

For many years, the Canadian biotechnology sector ranked only second to the US in terms of number of companies (Ernst & Young, 2009). Between 1990-2001, Canadian biotechnology firms vied with the UK for second place in the world in terms of patents in biotechnology (Munn-Venn & Mitchell, 2005). About 70% of Canadian biotechnology firms are estimated to work in the health sector (BIOTECansda, 2010). One example of Canadian health biotechnology firms' success stories is that of the Montreal-based start-up BioChem Pharma, which developed the world’s first anti-retroviral compound (Niosi & Hade, 1995). Another example is that of the Vancouver-based firm, QLT Inc., which was the first to have developed and commercialized a therapeutic treatment targeting forms of age-related macular degeneration, a leading cause of blindness in older adults (QLT Inc. website; Tapon et al., 2001). However, in recent years the performance of Canadian biotechnology companies has been strained. Stresses faced by the global pharmaceutical sector as well as the global economic downturn have led to Canadian biotechnology firms having considerably less access to financial support. Between 2007 and 2008, Canadian biotechnology firms' revenues declined by 9% (Ernst & Young, 2008). By the end of the year 2008, more than half of Canadian biotechnology companies had less than a year's worth of cash remaining (Ernst & Young, 2009). Analysts have
recommended that by having a comprehensive global strategy that includes a focus on emerging economy markets and partnerships may help Canadian firms to weather the financial storm in North America (Dufour, 2002; Munn-Venn & Mitchell, 2005).

Recent case study research suggests that Brazil and India are witnessing the rise of home grown health biotechnology sectors (Frew et al., 2007; Rezaie et al., 2008). Here, the Brazilian and Indian sectors are considered in turn. As mentioned earlier in this chapter, Brazil has focused on promoting biotechnology in the country from the 1970s onwards, and government initiatives to encourage efforts of Brazilian biotechnology firms continue today. A part of Brazil’s strategy has been to promote private sector development (Ferrer et al., 2004; Neto, 2006; Rezaie et al., 2008). Ferrer and colleagues (2004) report that 70% of local firms engaged in biotechnology-related activities in Brazil were private, 5% were Brazilian state-owned and the rest were foreign-owned. Health products are primarily targeted towards the domestic market (Guennif & Ramani, 2008; Rezaie et al., 2008). In recent years, Brazil has been witnessing a 10% growth in terms of its pharmaceutical market (Cavanagh, 2010), and as such the Brazilian market is increasingly lucrative to national as well as international firms. Brazilian health biotechnology firms embarked on their R&D programs by first focusing on the development of biogenerics. The Belo Horizonte-based Biobrás, which developed its own proprietary bacterial expression system for the production of recombinant human insulin in the 1990s, was regarded as being one of the strongest Brazilian success stories in this field (Ferrer et al., 2004). More
recently, Brazilian firms including Pele Nova Biotecnologia (Sao Paulo, Brazil) are developing therapeutics extracted from Brazilian biodiversity (Rezaie et al., 2008). Rezaie and colleagues observe that Brazilian health biotechnology firms still lack the capabilities to carry out complex R&D initiatives, and in order to boost their innovation potential are indicating interest in linkages with knowledgeable partners in northern countries.

Indian firms’ entry into the generics pharmaceutical sector began with the Indian government amending its Patent Act in 1970, which allowed local manufacturers to patent processes. The change in legislation enabled domestic Indian firms to build strong capabilities in reverse engineering and generic manufacturing, and provide affordable drugs to the Indian population (Kumar et al., 2004; Chataway et al., 2007). Indian pharmaceutical firms now reportedly have 8% share in the global pharmaceutical market, and annual turnover of approximately US$ 19 billion (Kiran & Mishra, 2009). Not only is India largely self-sufficient in terms of generic drugs, the Indian sector exports generics to markets in North America, Europe, Latin America and Africa (Export-Import Bank of India, 2007). Indian firms turned to biotechnology as a means to strengthen their innovation potential (Frew et al., 2007; Kumar et al., 2004). They ventured into developing biogenerics as their first foray into biotechnology; Shantha Biotechnics (Hyderabad, India), for instance, developed an affordable hepatitis B vaccine for the Indian population using its own novel expression system. Bharat Biotech, also based in Hyderabad, India, is working with international philanthropic organizations on vaccines for malaria and rotavirus (Frew et al., 2007). Frew and
colleagues observe that Indian firms working in the health biotechnology field employ a hybrid business model whereby they perform cost-effective contract R&D, clinical trials or manufacturing services for foreign clients, primarily from northern countries, to earn revenues which are channeled back into their discovery projects. Their research reveals that Indian firms are interested in increasing ties with northern partners for contract services and to gain from their expertise and knowledge so that they can continue to build their own R&D capacities. Some Indian pharmaceutical companies aggressively acquire northern firms that have a strong patenting record in order to boost their own intellectual property portfolio. However, they, too, are targets for acquisition by multinational pharmaceutical companies (Express Pharma, 2010). Still, the potential for mutually beneficial firm-to-firm collaboration between Canadian and Indian firms in health biotechnology can exist.

2.6.2 Examining Canada-emerging economies entrepreneurial collaboration in health biotechnology

I did not come across any previous studies that have specifically looked at the extent of Canada’s firm linkages with developing countries in health biotechnology. Based on results obtained from Statistics Canada’s 1997 Biotechnology Firm Survey, Traoré (2001) explores Canadian biotechnology firms’ international partners. There are a number of reasons why Traoré’s data set is limited for the purposes of my dissertation. First, it is dated; the data is more than ten years old. Biotechnology is a rapidly evolving field, and results from a survey from over a decade ago will not reflect the international
collaborative scene now. Secondly, the data set does not consider the field of health biotechnology specifically. Finally, Traoré uses broad geographic categories – Asia, Latin America, European Union, etc – to analyze the results. Findings are reported in aggregate within these geographic categories and it is not possible to gauge the levels of Canadian biotechnology firms’ partnerships with individual developing countries.

Science-Metrix’s 2003 mapping study on Canada-India S&T partnerships has a technometric analysis component whereby it measured the number of joint patents granted to Canadian and Indian assignees by the US Patent and Trademark Office in all technological fields in the 1990-2002 period. This work identifies firm collaborators working in high technology fields in Canada and in India. But a drawback of this study is that examining co-patents will not bring to light all entrepreneurial partnerships between Canada and emerging economies partners. This is because there are many types of inter-firm economically significant linkages where co-patents are not generated. Also, not all inventors choose to protect their inventions by filing patents. Relying on co-patents as a means to gauge collaborative activities thus may not give a complete picture of the extent of firm collaboration between Canada and developing countries partners. Science-Metrix’s data is also out of date for the purpose of this research, and its scope is limited to only looking at Canada-India collaborations.

There is need for more recent, targeted empirical data regarding the levels and attributes of Canada’s scientific and entrepreneurial collaboration in health biotechnology with developing countries and emerging economies. The studies,
which have looked at Canada’s entrepreneurial collaboration with developing countries in S&T fields, have relied on survey and technometric analyses. Although these methods can give a broad perspective of the S&T collaboration terrain, they cannot reveal important factors that shape the partnership. To better understand the dynamics of Canada-emerging economies health biotechnology collaboration and the factors that shape it, case study methodology is useful. This type of research methodology would include directly consulting with entrepreneurs who are involved in cooperation about their experiences.

2.7 Frameworks for analyzing north-south S&T collaboration

It is clear from the discussion above that there are various factors that can influence Canada’s health biotechnology collaboration with the emerging economies. There is need for a conceptual framework with which to analyze north-south S&T partnerships that take into consideration the important role context plays in whether collaborative projects lead to joint innovation. Scholars have attempted to understand north-south S&T collaboration from various perspectives. In this section, I review the new invisible colleges and the global value chain analytical approaches to examine north-south S&T linkages. The new invisible college concept primarily deals with research collaboration whereas the global value chains concept pertains to inter-firm linkages. Finally, the relevance of the systems of innovation analytical framework to study north-south S&T collaboration is discussed.
2.7.1 New invisible colleges

Wagner (2008) examines north-south research collaboration. She discusses how information and communication technologies as well as globalization forces have greatly facilitated knowledge flows between nations resulting in the rise of organic, self-governing international knowledge networks or ‘new invisible colleges’. According to Wagner and Leydesdorff (2005), the international scientific community is self-organizing, and the selection of research topics, research locations and partners depend on the individual choices of the scientists. Wagner (2008) argues that in an era marked by increased globalization, southern countries have new opportunities to participate in, contribute to and benefit from invisible colleges. However, she is careful to point out that southern researchers can still be limited in their access to invisible colleges. Unfamiliar with the norms of these networks, they may find it difficult to break into international scientific communities. Wagner’s conceptualization of ‘new invisible colleges’ emphasizes that the internationally networked science system can gain from partnership with southern researchers.

Wagner discusses the issue of governance in contemporary cross-border research cooperation in her work. She argues that as the emerging system of science is global in nature, nation states’ governance models of science, which are rooted in science nationalism, can find it difficult to effectively foster it. Other scholars (for example, Carlsson, 2006; Dufour, 2002; Edquist, 1997; Nelson, 1993; Patel & Pavitt, 1994), however, discuss the significant role national institutions and national policies have in terms of influencing a country’s scientific
and innovation related activities, including its approach to international science. This large body of research indicates that policy instruments put in place by various national governments have played an important role in countries’ S&T trajectories. The ‘new invisible college’ concept does not appear to place emphasis on examining the role of national institutions in its analysis of international collaboration, and in doing so fails to give weight to a critical body of knowledge furthered by science policy studies.

2.7.2 Global value chains

Linkages between northern and southern firms in diverse sectors, including electronics, automobiles, apparel, agricultural produce, have been examined by global value chain analysis (for example, Gereffi et al., 2005; Pietrobelli & Rabellotti, 2010). The concept of global value chains captures the functional integration of activities of different firms that are dispersed geographically, often in different countries. The chain of activities required to bring a product to end users is broken down into discrete functions – conception and design, production, marketing, distribution – and shifted to locales where they can be carried out at effectively and at low cost. Such global networks are regarded to have the potential to enhance knowledge diffusion across firm boundaries and national borders. Global value chains can be a means for southern firms to overcome some of their knowledge-related disadvantages; scholars consider their participation in these networks to be helpful in enabling them to upgrade their technical and managerial capabilities (Ernst 2002; Ernst & Kim, 2002; Pietrobelli & Rabellotti, 2010).
Lead firms are considered to be at the heart of global value chains, and it is their strategy and direction that affect supplier firms’ growth and organizational position in value chains. Functions of global networks are dispersed across nations, but there is a tendency of lower-end production activities concentrating in southern supplier firms whereas high-end R&D agglomerates in northern lead firms (Ernst, 2002). Despite Gereffi et al.’s (2005) reporting of a variety of relationships possible between lead and supplier firms, ranging from captive to more relational interactions, the overall strategy of global value chains is primarily under the control of lead firms. Such hierarchy in firm relations has been reported in industrial sectors including automobiles and consumer electronics. However, it is not clear how well suited the concept is to examining a sector such as biotechnology where directionality and a chain of command in firm networks has not been reported (Powell et al., 1996).

Another drawback of the global value chains analysis is that it does not pay attention to the institutional context within which the firms that comprise the chains are embedded (Ernst, 2002). Pietrobelli and Rabellotti (2010) observe that the institutional context likely interacts with and influences governance as well as learning and innovation capabilities of global value chains in multiple ways, but acknowledge the need for further research on this matter. Considering north-south S&T collaboration in conjunction to its wider context is critical to understanding the dynamics of partnership. The strength of the global value chain concept is that it enables consideration of power relations between the international firms within the chain. However, it does not allow for analysis of
institutional context, and thus, it has limited applicability as a framework for studying north-south linkages in a systemic manner.

2.7.3 Systems of innovation

The systems of innovation concept was developed in parallel by Freeman, Lundvall and Nelson during the 1980s to understand the relationship between technological progress and economic development. Their initial work operated at the national level and highlighted the role of state action and national policy in these processes. The core contribution of the systems of innovation concept is that it deviates from a linear approach to technological progress and emphasizes non-linearity and interaction between various social actors as being critical to innovation. The systems of innovation framework conceives of innovation as being influenced by numerous complex factors, that the process is interactive and dynamic. Innovation systems consist of institutions that are involved in the creation, diffusion and use of new, economically useful knowledge. These include formal institutions such as firms, universities, research institutions, government agencies, financial institutions, regulatory bodies. They also include informal institutions such as social and cultural norms. These institutions are held together by a web of linkages and synergies, and it is the multidirectional knowledge flows and interactions between these various actors that contributes to the innovation process. The influences of these institutions and social actors can both provide constraints as well as incentives to the behaviour of an
innovating agent (Lundvall, 1992; Nelson, 1993). Lundvall et al. (2010, p.6) propose the following definition of innovation systems:

“The national innovation system is an open, evolving and complex system that encompasses relationships within and between organizations, institutions and socio-economic structures which determine the rate and direction of innovation and competence-building emanating from processes of science-based and experience-based learning.”

The early research on the national systems of innovation concept was developed in connection with developed nations including Denmark, Norway, Sweden, the US, the UK, Germany, Japan and Canada. There has been skepticism among scholars whether the systems of innovation concept is appropriate for applying to the case of developing countries. Arocena and Sutz (2000), for instance, have argued from the point of view of Latin American countries, particularly Uruguay, that there is no full-blown system of innovation in the south. Viotti (2002) similarly does not view developing countries as having well-structured and efficient national systems of innovation. However, Lundvall et al. (2010) suggest that in relying on a broad understanding of innovation that takes into consideration incremental innovation, diffusion, adaptation of new technologies in addition to radical innovation can help bring to light elements of the innovation process in the southern context.

The systems of innovation conceptual framework has been gaining currency among scholars as a framework to study north-south collaboration (Chataway et
These scholars observe that in order to unlock the potential of north-south collaboration and to mitigate its risks, it is important to understand the complex realities and institutional environment where collaborative projects are implemented. Velho (2002) points to the systems of innovation framework as a conceptual tool to analyze programs that promote north-south S&T partnerships. She proposes that analyzing north-south research partnerships from a systemic perspective gives a clearer and more comprehensive view of the complexities involved in such international collaboration. Velho considers the analytical merits of relying on the systems of innovation framework to study north-south collaboration. As the framework brings diverse social actors, institutions and their influences to the core of analysis, it is well suited to examine north-south collaboration, a phenomenon where contextual issues are key. Another advantage of the systems of innovation concept that Velho finds useful in studying north-south collaboration is its broad definition of innovation and knowledge that take into consideration both science as well as experience based learning. A broader view is better able to capture the breadth of learning and economic activity in developing countries, which otherwise may be missed in analyses. Finally, Velho considers the systems of innovation framework to be an important tool for informing policy on north-south collaboration; applying the systems of innovation framework to study north-south S&T partnerships can enable evaluating institutional interactions and knowledge flows, recognizing bottlenecks, and identifying opportunities for policy remediation.
However, a drawback in Velho’s conceptualization of using the systems of innovation framework to study north-south S&T collaboration is that it pays unequal attention to the institutional context in the south versus that in the north. In her work, Velho ignores stakeholders in the north and she appears to give priority to relevant actors in the southern setting. This is because her main concern is how north-south collaboration can contribute to addressing development challenges experienced in developing countries. A major criterion that marks success of north-south collaboration for Velho is the ability of the partnerships to achieve development goals in the south. While this is indeed a key concern, what Velho neglects to elaborate on is that if north-south S&T collaborations are to be long-term and sustainable in nature, it is important that they result in innovation for both parties involved.

Velho argues that adopting the systems of innovation conceptual framework to analyzing north-south collaboration can help overcome linear conceptions in S&T relations between developed and developing countries. This can enable the discussion on north-south S&T collaboration to move away from donor-recipient dynamics, a concept that becomes less relevant with emerging economies such as Brazil and India rising as home to increasingly robust scientific communities and as strong contributors of resources to bilateral S&T initiatives. However, in not affording equal attention to northern and southern innovation systems when thinking about S&T collaboration between developed and developing countries, Velho is unable to make a sufficient break away from the aid-driven, linear paradigm that has dominated the dialogue on north-south relations. In order to
make the shift, there is need for research that examines north-south collaboration by considering the partnership’s connections to wider innovation systems actors in both the south and the north.

2.8 Key gaps in the literature and dissertation aims revisited

In this chapter I have presented the main literature on north-south S&T collaboration, and made particular attempt to relate it to the field of health biotechnology. What reviewing the literature brings to light is that policymakers, scientists and entrepreneurs in the north have shown little interest in harnessing the research capabilities in southern countries to address development challenges. This was partially because science was neglected in developing countries for a long time, and thus, local capacity remained weak. Social reasons have also likely resulted in bias against southern science. For instance, studies have shown that scientific articles from developing countries in high impact international peer reviewed journals are cited less frequently than articles from developed countries from the same journals. Bias from editors, reviewers and citers who may be unfamiliar with the southern academic environment that produced the research can have a role in this body of work being overlooked (Akre et al., 2011; Meneghini et al., 2008).

The literature suggests that lack of awareness of research endeavours and achievements in the south is potentially a reason why northern donor agencies
and scientific communities have ignored indigenous southern research capabilities and resorted to ‘linear’ measures by which science created in the north was transplanted to the south to solve southern challenges. However, the literature also shows that the economic standing as well as science capacity in the emerging economies, including in fields such as health biotechnology, is strengthening in recent years. Burgeoning southern capabilities in this field may be engaging the interest of northern scientific and entrepreneurial communities. Northern scientists and entrepreneurs may be beginning to see the value of southern research to expand the scope of their scientific activities. For the south, collaboration with northern peers has been known to help them bring their research activities further into the mainstream (Meneghini et al., 2008). However, southern scientists and entrepreneurs may also be reaching out to northern counterparts in order to complement their local capacities and complete projects.

Critical shifts in capabilities and attitudes may be leading to the formation of north-south S&T partnerships based on equity in terms of roles and towards attaining mutual gains. In face of such changes, policymakers in the north will have to redefine their measures to promote north-south S&T interactions. They will have to recognize the evolving roles of the northern and southern parties in collaboration to help the partnership progress in a way that it leads to joint innovation. The aim of my dissertation is to see if these transitions are indeed taking place.

The literature review reveals that although previous research has been carried out to learn about north-south S&T collaboration, there are areas that would
benefit from further investigation. Reviewing the literature shows that little investigation has focused specifically on Canada’s health biotechnology collaboration with the emerging economies. There is scanty information available on levels of both research as well as entrepreneurial collaboration in this regard. Without having an overview of the extent of partnership, it is difficult to gauge the potential of such cooperation. Also, without having baseline data to compare to, it will be difficult to assess the effectiveness of any public policy that is implemented to encourage Canada-emerging economies health biotechnology collaboration. Thus, the first objective of my research is to measure levels of Canada’s research as well as entrepreneurial collaboration in health biotechnology.

There is limited understanding of the motivations for entering into Canada-emerging economies health biotechnology collaboration, the barriers encountered by collaborators and the benefits that are achieved. The literature review reveals that knowledge regarding these areas is particularly lacking for collaboration involving firms. The second objective of my research is to gain greater insight into these issues. Without greater knowledge of these areas, it is difficult to understand the factors and conditions that influence the partnerships. For instance, the literature review reveals that there is an emerging tendency of studies on north-south S&T collaboration to focus on perspectives of the south when looking at challenges encountered in partnerships. This dissertation aims to take a wider perspective and consider reflections of scientists and entrepreneurs from Canada as well as Brazil and India. Additionally, the views of
policymakers in the three countries who are in a position to support and influence Canada-Brazil and Canada-India S&T collaboration are elicited. In interviewing these key informants, it is possible to gain greater understanding of the contextual issues in such international collaboration both from the south and the north.

An important aim of this dissertation is to consider the wider institutional context north-south S&T collaboration is embedded in. The literature suggests that public policy designed to encourage north-south S&T relationships traditionally viewed such interaction in a ‘linear’ mode, which assumed developing countries could not produce knowledge themselves and needed the transfer of professional, objective knowledge from developed countries. The linear paradigm left no room for partnership and ignored consideration of the influences southern and the northern institutions exert on north-south S&T collaborative initiatives. The research in this dissertation aims to rectify this by examining north-south S&T collaboration using the lens of the systems of innovation framework, which brings institutions as well as policy issues in Canada and the emerging economies to the core of the analysis. Thus, the third objective of my project is to advance a conceptual framework by which to better understand and analyze north-south S&T partnerships from a systemic perspective.

To reiterate, my goal in this dissertation is to address the following areas. I aim to obtain empirical data on north-south S&T collaboration by examining levels and characteristics of Canada-Brazil and Canada-India health biotechnology partnership, both research and entrepreneurial. I seek to gain deeper conceptual
insight into the processes north-south collaboration in the health biotechnology field by analyzing collaboration between Canada-Brazil and Canada-India. Based on the findings of this research, I aim to suggest potential policy areas Canadian public policy can consider to guide its approach to facilitating S&T cooperation with the emerging economies. This is to fulfill the fourth and final study objective laid out in the introductory chapter of this dissertation; that is, to reflect on my research findings and suggest how Canada can foster S&T collaboration with southern countries such that it results in mutual benefits and joint innovation.
Chapter 3

Study methods

3.1 Introduction

In this chapter I describe the research methodology used to address the study’s aims. A mixed methods procedure was used in this dissertation. Mixed methods research design combines both quantitative and qualitative forms of inquiry. For complex social phenomenon more insight may be gained by integrating quantitative and qualitative methods in mixed methodology than either form on its own (Creswell, 2009).

Quantitatively mapping research and entrepreneurial collaboration in health biotechnology between Canada and the emerging economies gave a broad overview of the current levels of their linkages in this field. In measuring the extent of collaboration, it was possible to gain a macro level understanding of the phenomenon. Mapping also provided a baseline to which future studies on this topic can compare, thereby affording the possibility to evaluate changes over time, and also the successes of initiatives promoting such north-south collaboration.
Quantitative methods is a good first step by which to begin learning about Canada-emerging economies collaboration in health biotechnology, but it does not give a full picture of the topic. There are issues that quantitative analysis cannot shed light on. Interactions between social actors are difficult to examine using quantitative methods. A more promising strategy is to rely on their views and perspectives. Interviewing collaborators and institutional actors in Canada, Brazil and India enables gaining deeper insight into their interactions, and also how the broader institutional context in partners’ countries affects collaboration.

3.2 Mapping collaboration

In this project, I measured levels of Canada’s collaboration with developing countries in health biotechnology. Levels of both research collaboration and firm collaboration were gauged. The study also aimed to map the geography of Canada-developing countries health biotechnology collaboration and main features of these linkages. Examining the institutional origins of Canada’s collaborations with Brazil and India were among the main objectives of this dissertation.

3.2.1 Mapping research collaboration

To evaluate the extent of Canadian researchers’ health biotechnology collaboration with colleagues in Brazil and India, I examined the levels of health
biotechnology papers produced by Canadian scientists in collaboration with Brazilian and Indian co-authors. In such 'scientometric' analysis, I used Canada-Brazil and Canada-India health biotechnology co-publications in international peer-reviewed journals as a proxy for their partnership.

A database that contains bibliographic information on scientific journals published worldwide is necessary for scientometric studies. The analysis in this dissertation relies on Thomson ISI’s Science Citation Index Expanded database (SCI Expanded). The SCI Expanded database indexes over 6,000 of the world’s most cited, refereed journals (Science Citation Index Expanded website). Unlike Medline, which provides only the address of the first author, SCI Expanded collates the names and institutional address of all authors of a publication, thus enabling analysis of collaboration between various institutions as well as countries. It has been noted that SCI Expanded is more inclined to include journals published in English than in other languages (Archambault & Vignola-Gagné, 2004; Arunachalam & Manorama, 1988). This is a drawback when evaluating scientific productivity of countries where English is not the national language because a part of their scientific output is likely not to be included in the analysis. However, since this study examines collaboration and is interested in Brazilian and Indian co-publications with Canadian researchers, these co-authored papers are likely to be published in English journals (and in fewer instances in French). Thus, these co-authored papers are likely to be included in the SCI Expanded database. For this study, only articles, notes, reviews and
conference proceedings were considered. These have been through the peer review process and constitute a core medium for knowledge diffusion.

The firm Science-Metrix\(^1\) (Montreal, Canada) was contracted to extract Canada-Brazil and Canada-India scientific co-publications in health biotechnology from the SCI Expanded database in the period 1993 to 2004. Science-Metrix retrieved health biotechnology co-authored papers from the database using keyword-in-title searches. These keywords were selected in the following manner: first, papers were randomly selected from journals specializing in biotechnology, and then keywords and keyword combinations were chosen from the titles of these papers to extricate other papers in the field of biotechnology. In order to choose the health biotechnology subset of papers, biotechnology papers published in journals classified by the National Science Foundation under the fields of biomedical research, clinical medicine and health sciences were retained.

The scientometric data extracted from the SCI Expanded database provided the total number of papers Canadian scientists collaboratively authored with Brazilian and Indian counterparts, and also trends in their co-publication over the 1993-2004 time period. I used Microsoft Excel to graphically represent these statistics. The extracted data gave insight into the types of sectors and institutions (firm, university, hospital, etc) Canadian, Brazilian and Indian collaborators belonged to in their countries. The scientometric analysis also helped to understand the

\(^1\) http://www.science-metrix.com/
geographical dispersion of Canadian, Brazilian and Indian co-authors in their countries.

Science-Metrix provided updated scientometric data on north-south collaboration in health biotechnology in 2010. It provided levels of health biotechnology co-publications between northern and southern countries between the years 1994 and 2009. The firm produced these data using the Scopus database (Scopus website). Scopus has a more extensive coverage of scientific journals from developing countries than the SCI Expanded database. It includes more than 15,000 peer-reviewed journals. Scopus, like SCI Expanded, links authors of papers to their institutional addresses. Articles, conference papers and reviews were considered. Co-authored papers were retrieved from Scopus using keyword-in-title and –in-author-keyword searches to specifically derive biotechnology papers. Science-Metrix randomly selected papers from journals specializing in biotechnology; keywords and keyword combinations were then chosen from the titles and author keywords of these papers in order to retrieve other papers in the field of biotechnology. Subsequently, a subset of papers from the biotechnology dataset was built to delineate the domains of health biotechnology. For the health biotechnology subset, the National Science Foundation classification was used to retain only biotechnology papers published in journals classified in the following subfields: biomedical research, clinical medicine, and the health sciences. In addition, papers that were found in Medline and that are attached to the meshterm “human” were kept in the health
biotechnology dataset. Finally, Science-Metrix performed keyword searches to identify additional papers related to health within the biotechnology dataset.

### 3.2.2 Mapping firm collaboration

To examine the level and broad characteristics of Canada’s entrepreneurial collaboration with developing countries in health biotechnology, I surveyed Canadian health biotechnology firms. The survey asked if the firms had any links with partners in developing countries and if so, asked them to answer brief questions about these partnerships.

I used Industry Canada’s, BIOTECanada’s and Contact Canada’s public databases to identify the names of Canadian health biotechnology firms for the survey. First, I combined these databases into one. Then I collected additional information on the types of activities each firm engaged in from their websites. Finally, I excluded the firms not involved in health biotechnology (i.e. firms involved in agri-biotechnology, veterinary biotechnology, industrial biotechnology, environmental biotechnology, biofuels, cosmetics, consulting and investment). The final list included Canadian biotechnology firms involved in biopharmaceuticals, pharmaceuticals, diagnostics, bioinformatics, regenerative medicine, laboratory services, clinical trials, contract research, natural remedies and nutraceuticals. Consensus had to be reached within the project’s team members in determining whether a firm was removed or remained on the list. For
publicly listed Canadian health biotechnology firms that were on the list, I collected financial data (total assets, R&D expenditure, total revenues, etc) from the database FP Advisor and from annual reports on their websites.

A survey containing ten questions was sent to the CEOs or Heads of R&D or Heads of Business Development in health biotechnology firms in Canada (see Appendix A for full survey). To encourage a good response rate, I kept the survey questionnaire brief. The survey questionnaire was first administered with the aid of an online survey service, Instant Survey\(^2\), to make it easier for firms to respond. I then made follow-up phone calls to companies that did not respond to the survey online. If not completed online, the survey was conducted over the phone and responses were documented. I sent responses back to the firms for verification.

The survey was sent to 259 Canadian health biotechnology firms. I examined the extent of Canadian health biotechnology firms’ north-south collaboration at the aggregate level. To visually represent the geographical dispersion of the linkages, I mapped the findings using the social network analysis software Ucinet 6. Additionally, I analyzed the characteristics of Canadian firms’ north-south linkages, including the types of joint activities involved, the reasons for the collaborations, the types of technologies involved, the forms of arrangements established.

\(^2\) http://www.instantsurvey.com/
3.3 Case study research

To gain detailed understanding of Canada’s health biotechnology collaboration with Brazil and India, I carried out case study research. Case study research is conducted to understand complex social phenomena (Stake, 1995; Yin, 2009). In this strategy of inquiry, phenomena over which researchers have little control are explored in depth. These can include a program, an event, or an activity. Case study evidence can come from a number of sources such as interviews, direct observation, documentation. The use of multiple sources of evidence allows investigators to address a broader range of issues and to retain the richness and holistic characteristics of the phenomenon under examination. The case study approach was deemed to be appropriate for my dissertation; it can help gain in-depth understanding of Canada’s collaboration with the emerging economies in health biotechnology.

For the purposes of this dissertation, two case studies have been conducted: the Canada-Brazil and Canada-India bilateral relationships in health biotechnology. More case studies are required to identify the complete range of traits and characteristics of Canada’s collaboration with the emerging economies in health biotechnology. However, the scope and financing of this dissertation does not allow for more than two cases to be examined.
The central feature of my case study research was conducting face-to-face, semi-structured interviews with partnering researchers and firms in Canada-Brazil and Canada-India collaborative health biotechnology projects, as well as relevant key informants in the three countries. The case study research method enabled me to include a variety of stakeholders’ perspectives. Conducting interviews enabled me to gain insight into the views of Canadian, Brazilian, and Indian researchers and entrepreneurs who have experience with collaboration. I also elicited the perspectives of policymakers who promote international S&T collaboration in Canada, Brazil and India.

The mapping exercises helped to identify which collaboration initiatives to examine in more detail. I chose specific research partnership projects from the pool of Canada-Brazil and Canada-India co-publications identified by the scientometric analysis for in-depth study. Criteria for choosing collaborations to study included joint projects that have resulted in co-publications with relatively high citation rates. I placed emphasis on including research collaboration initiatives that have led to more than a single co-publication. Also, I chose research collaboration initiatives that involved institutions from different cities in Canada, Brazil and India.

With respect to entrepreneurial collaboration, for further research I selected Canada-Brazil and Canada-India firm partnership initiatives from the pool identified by surveying Canadian health biotechnology firms. Firm collaboration
initiatives involving R&D activities, contract services and manufacturing were prioritized in terms of selection for in-depth study. To increase accuracy of data collected, and to see if the perspectives of international collaborators are different, I interviewed both the Canadian and the emerging economies sides.

To explore how collaboration initiatives fit into the innovation systems of Canada, Brazil and India, I examined the roles of various institutions involved in supporting international collaboration (including ministries of S&T, funding agencies, ministries of trade, regulatory agencies, embassies and trade commissioners, intellectual property experts, venture capital firms, etc). Key informants interviewed at these institutions were identified through internet searches as well as snowball sampling. Snowball sampling is a method whereby an interviewee from the initial pool suggests other knowledgeable individuals who may be able to contribute their insights to the study (Marshall & Rossman, 2011).

I developed interview guides based on the aims of the study (see Appendix B for full interview guides). I asked collaborators in Canada-Brazil and Canada-India health biotechnology research and entrepreneurial partnerships about the potential, challenges and impacts of cooperation. In the three countries, I interviewed wider members of the local health biotechnology system to gain better insight into policies and programs that can promote north-south collaboration in health biotechnology and in S&T generally. Initial interview guides I drafted were submitted to the larger research group for feedback. I used
the revised version of the guides for conducting the interviews. Additionally, to facilitate the pursuit of emerging themes, I refined interview guides during the field work.

Email invitations were sent to scientific and entrepreneurial collaborators to take part in the study (see Appendix C for invitation letter). The vast majority of the interviews were carried out at interviewees’ institutions. In three instances, phone interviews were conducted as the study participants were not available when I was conducting field work in their cities. Prior to the beginning of the interview, consent forms were signed and a copy was given to the participant. The consent form was reviewed with each participant and all questions were addressed. When interviews were conducted over the phone, the consent form was either faxed or sent electronically.

During the actual interview, I tried to keep the exchange as conversational as possible, and as a result, the interview guide was not rigidly adhered to. At times interviewees expanded on issues or started answering a question that came later in the interview guide. They were not stopped but encouraged to go on. I was careful not to lead the interviewees or to suggest answers. At the end of the interview, I asked the participants if they had any questions or comments. In most cases the interviews were carried out in English, but a few interviews in Brazil were carried out in Portuguese with an interpreter present. The interviews
lasted from around 40 minutes to approximately 3 hours. Interviews were recorded digitally.

When interviewees consented to their participation, but not to being voice recorded, I took notes trying to write down the exact phrasing of the interviewees. Audio files from the recorded interviews were transcribed. A total of 104 interviews were conducted in Canada, Brazil, and India. These are presented below in Table 1.

<table>
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<tr>
<th></th>
<th>Scientists</th>
<th>Firms</th>
<th>Institutional actors</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Canada</strong></td>
<td>13</td>
<td>11</td>
<td>27</td>
<td>51</td>
</tr>
<tr>
<td><strong>Brazil</strong></td>
<td>10</td>
<td>7</td>
<td>10</td>
<td>27</td>
</tr>
<tr>
<td><strong>India</strong></td>
<td>8</td>
<td>7</td>
<td>11</td>
<td>26</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>31</td>
<td>25</td>
<td>48</td>
<td>104</td>
</tr>
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</table>

In Figure 1, I indicate the cities in Canada, Brazil and India where field work was carried out. The various actors interviewed in the three countries are presented in accompanying charts. Interviews were conducted until the point of saturation was reached, that is collecting additional data did not yield any new themes being discovered.
Figure 1. Field work in Canada, Brazil and India

<table>
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<tr>
<th>Type of actor</th>
<th>Number of interviews</th>
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<tr>
<td>Scientists</td>
<td>13</td>
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<td>Firms</td>
<td>11</td>
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<td>Institutional actors</td>
<td>27</td>
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<td><strong>Total</strong></td>
<td><strong>51</strong></td>
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### Brazilian interviews

<table>
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<th>Type of actor</th>
<th>Number of interviews</th>
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<tr>
<td>Scientists</td>
<td>10</td>
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<td>Firms</td>
<td>7</td>
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<tr>
<td>Institutional actors</td>
<td>10</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>27</strong></td>
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## Indian interviews

<table>
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<th>Type of actor</th>
<th>Number of interviews</th>
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<tbody>
<tr>
<td>Scientists</td>
<td>8</td>
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<tr>
<td>Firms</td>
<td>7</td>
</tr>
<tr>
<td>Institutional actors</td>
<td>11</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>26</strong></td>
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</table>
In Canada, Brazil and India, interviews were carried out with a diversity of institutions. In Canada, they included technology transfer units, provincial S&T agencies, federal funding agencies, aid agencies, university and industry associations, regulatory authorities. In Brazil, I conducted interviews with experts on research ethics and intellectual property rights (IPR), regulatory authorities, trade officials, funding agencies, the ministries in charge of health, higher education, and S&T. I also spoke with representatives from a Brazilian incubator and a venture capital firm. In India, Indian funding agencies, the drug regulatory authority, ministries responsible for S&T as well as biotechnology, trade officials, IPR experts, and a venture capital firm were among the local institutional actors I interviewed.

I collected extensive background information on the specific collaboration projects chosen for in-depth study. These included scientific papers, joint patents, and other outcomes of the collaboration. Where available, I collected annual reports from firms involved in the collaborations, government reports and other government documentation such as policy briefs, descriptions of existing policies, priorities and initiatives, legal and regulatory arrangements. Content from websites of institutions and firms served to supplement the other data sources. One of the major strengths of case study research is being able to use many different sources of evidence. When multiple types of evidence converge or triangulate on the same findings, it increases the accuracy and robustness of the study’s results (Yin, 2009). Being able to interview Canadian, Brazilian, and
Indian scientific and entrepreneurial partners as well as key informants, and to collect diverse documentation regarding the joint projects studied, provided the possibility of comparison and examination of consistency of interview responses. This process of triangulation allows corroboration of the observed phenomenon and to clarify its meaning.

I analyzed the data on Canada-Brazil and Canada-India health biotechnology collaboration using qualitative coding procedures (Strauss & Corbin, 1998; Charmaz, 2007). First, the data was read to achieve a good working knowledge of the content. Then I identified portions of the data related to a similar concept or idea were identified and labeled them in what is called ‘open coding’. Third, I identified similar themes labeled in open coding and organized them into conceptual categories. This is called ‘axial coding’. Finally, I identified core concepts and organized other conceptual categories in relation to the core concept in ‘selective coding’. During each step, memos recorded the coding procedures taken. The codes and themes were developed in consultation with other members of the research team. I frequently discussed codes and themes with my supervisor and other graduate students. Findings were presented to my program advisory committee on a regular basis for feedback, to suggest rival explanations and possibilities, and to help ensure reasonableness of findings. These meetings provided an opportunity to discuss and explain the rationale behind the data analysis. While consensus was achieved for most of the codes and themes identified, some concepts were re-analyzed as a result of the
discussions. In addition to consultations regarding data analysis within the research team, member checks were conducted whereby interviewees were sent descriptions of results and draft reports. Thus, member checks as well as internal review and discussions were important means by which to increase validity of the research conducted (Yin, 2009).

Stake (1995) argues that case study research provides a poor basis for generalization of its results. Rather the purpose of case study methodology is to produce particularizations – that is, shed light on the peculiarities and uniqueness of a specific case. However, Yin (2009) has a different opinion on this issue. According to him, case studies are generalizable not to populations, but rather to theoretical propositions. In this dissertation, I follow Yin’s advice; any generalizations are more concerned with concepts regarding processes of north-south S&T collaboration rather than trying to use the results to make predictions about any single collaboration initiative.

The protocol of the overall study on Canada-emerging economies collaboration in health biotechnology was approved by the University of Toronto’s Research Ethics Board. The consent form, survey questionnaire, and interview guides were part of the research ethics application. As per the research ethics proposal, all digital files and transcripts were kept on a secure, password-protected computer with restricted access. All field notes were stored in a locked cabinet.
3.4 Dissemination

I presented the research in this dissertation at national and international conferences. Articles were also written based on the findings of the dissertation. Additionally, in June 2010, I helped organize a workshop with the larger research group and in partnership with colleagues from the Department of Foreign Affairs and International Trade (DFAIT), IDRC and the Canadian Institutes of Health Research (CIHR) to present the research findings to Canadian federal and provincial policymakers. At the workshop, about 60 attendees provided thoughtful feedback regarding policies proposed from the research to encourage Canada’s health biotechnology ties with the emerging economies. The perspectives and insights of policymakers were critical in deepening conceptual themes emerging from the study.
Chapter 4

Mapping Canadian entrepreneurial collaborations with developing countries in health biotechnology

4.1 Introduction

To maintain their competitiveness in health biotechnology, firms in this sector have to form strategic alliances. These partnerships can cross international borders, and can increasingly involve companies in southern countries. As discussed in Chapter 2, capacity in the health biotechnology field is no longer limited to a handful of high income, northern countries. Developing countries themselves have been building up their expertise (Thorsteinsdóttir et al., 2004b), and starting their own firms in the field (Al-Bader et al., 2009; Frew et al., 2007; Frew et al., 2008; Rezaie et al., 2008). However, relatively little is known about the extent to which Canadian health biotechnology firms are engaging in collaboration with partners in developing countries and emerging economies. This chapter examines the extent of collaboration of Canadian health biotechnology firms with partners in developing countries. I map the geography of the linkages and explore the main characteristics and outputs of these collaborations.
To gauge the frequency and characteristics of Canada’s collaboration with developing countries, I sent a brief survey to all health biotechnology firms that could be identified in Canada. The survey questionnaire was sent to 259 Canadian health biotechnology firms, of which 181 responded. Thus, the response rate is about 70%. For a detailed discussion of the study methods, refer to Chapter 3. The findings of the survey exercise are presented in this chapter.

4.2 Level of firm collaboration

The survey results show that about a quarter (26%) of respondent Canadian health biotechnology firms are involved in north-south collaboration (Figure 2). Most firms that collaborate with developing countries are also actively collaborating with developed countries, which indicate that they seek alliances widely around the globe. Many of these firms have more than one north-south linkage. In total, Canadian firms reported 82 north-south collaboration initiatives with developing countries.
Nearly half (46%) of Canadian firms reported collaboration with partners in other developed countries only. Slightly more than a quarter of Canadian firms (28%) reported having no international collaborations.

Among the 181 respondent firms, 54 are publicly listed and 127 are private. A substantial number of both public and private firms (77% and 63% respectively) are involved in north-north collaborations. When it comes to north-south collaborations, Canadian public and private firms are less engaged in these (24%
and 27% respectively). These data indicate that there is not much difference in the levels of international collaboration between public and private firms.

4.3 Geographical extent of firm collaboration

The geography of Canadian health biotechnology firm’s collaborations with developing countries partners is mapped in Figure 3.

Figure 3. The geography of Canadian health biotechnology firms’ north-south collaborations

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3 Both the size of the red node and the width of the connecting line represent the number of collaborations the developing country has with Canadian health biotechnology firms.
Canadian firms have collaborations in all the main regions of the world. Their strongest developing country linkages are with China (22 of the 82 north-south collaboration initiatives reported in the survey exercise), and with India (17 collaboration initiatives). Both China and India have intensified their efforts to build domestic health biotechnology capacity in recent years (Kumar et al., 2004; Zhenzhen et al., 2004). This, combined with the large market potential of these countries is likely to make them lucrative partners for Canadian firms. The top four northern countries that Canadian health biotechnology firms collaborate with are the US (116 collaboration initiatives), UK (35 collaboration initiatives), Germany (23 collaboration initiatives) and Japan (18 collaboration initiatives). Thus, the results indicate that Canadian firms’ collaborations with China and India are approaching or surpassing their collaborations with leading developed countries in the health biotechnology field.

According to the survey, Canadian health biotechnology firms also work with countries in Latin America (21 collaboration initiatives). Several countries in Latin America, such as Brazil and Cuba, are active in health biotechnology (Ferrer et al., 2004; Thorsteinsdóttir et al., 2004c). The continent’s relative proximity to Canada and its wealth of natural resources may be additional factors that make Latin American firms attractive partners for Canadians.

In contrast, the level of Canadian firms’ partnerships with developing countries in East Asia and the Pacific (8 collaboration initiatives in total), the Middle East and
North Africa (5 collaboration initiatives in total) and sub-Saharan Africa (9 collaboration initiatives in total) is relatively low.

Melon et al. (2009) surveyed health biotechnology firms from six developing countries (Brazil, China, Cuba, Egypt, India and South Africa) focusing on their south-north collaborations. This study found that firms from these developing countries partnered most often with US companies. Partners in Germany, the UK, France and Canada follow in the rankings. The study noted that developing countries collaborate frequently with their former colonial powers even if the relevant northern country does not necessarily possess strengths in the health biotechnology field (data from authors). Similarities between bureaucratic structures and shared official languages may explain this trend. However, my study’s findings indicate there is interest among Canadian health biotechnology firms to enter into collaboration with developing countries partners. It is important for southern firms to diversify their linkages and focus on sectors that are strong in health biotechnology in countries like Canada.

The results of surveying Canadian health biotechnology firms reveal that almost all (90%) of these firms’ north-south collaborations involved at least one type of formal arrangement among the participants. These ranged from distribution agreements to joint R&D agreements. Licensing agreements were cited quite frequently, with over a fifth of the north-south collaboration initiatives being based on them. Joint ventures were rarer, being reported in only 12% of the
collaboration initiatives. The establishment of a subsidiary was reported in 13% of the collaboration initiatives. Subsidiaries are being set up not only by Canadian firms in developing countries, but also by developing countries’ firms in Canada.

4.4 Characteristics of firm collaboration

4.4.1 Types of joint activities

Canadian health biotechnology firms’ north-south collaborations involve different types of activities; 40% of firms report involving two or more types of activities in a single collaboration initiative. Collaboration activities cover all stages of the health biotechnology value chain (Figure 4).

Figure 4. Joint activities in Canadian health biotechnology firms’ north-south collaborations
Collaboration initiatives involving joint distribution ranked highest in frequency (30% of the 82 north-south collaboration initiatives). Collaborations involving joint R&D followed closely (28% of the collaboration initiatives). R&D collaborations are important for firms because these can help them generate novel products. Enhancing abilities in R&D can enable firms to identify, gain and exploit new knowledge. These types of gains and the intensity of knowledge flows in R&D collaborations are not typically present in collaborations that are limited to distribution activities.

Clinical trials, manufacturing, laboratory services and contract research are also reported as frequent collaboration activities. The collaborations also involve provision and use of supplies (including raw materials, active pharmaceutical ingredients, and so forth) and provision of training activities. These, however, are not as frequent.

4.4.2 Rationale for collaboration

The survey findings suggest that a complex mix of reasons drive Canadian health biotechnology firms’ collaborations with developing countries. In many instances, respondents reported several reasons for starting a single collaboration initiative.
Gaining access to developing countries’ market was the reason most frequently cited by Canadian firms for collaborating with developing countries (66% of the north-south collaboration initiatives). This is consistent with the observation that collaborations commonly involve marketing and distribution activities. The second reason most frequently cited by Canadian firms was to provide knowledge to their developing countries partners (37% of the collaboration initiatives). The firms reported accessing knowledge from their developing countries’ partners as the third most frequent reason for their collaborations (24% of the collaboration initiatives). These findings seem to indicate bi-directional knowledge flows between Canadian health biotechnology firms and their southern partners.

Canadian firms also cited both providing financing to developing country partners and accessing funding from partnerships with developing country firms (6% and 7% of the collaboration initiatives respectively) as reasons for their north-south collaborations. This reflects, once again, that resources are not necessarily streaming only from the north to the south in Canadian firms’ collaboration with southern partners.
4.4.3 Leveraging competitive advantages

Canadian health biotechnology firms report having strong R&D linkages with Chinese and Indian partners. As these two countries have been building their capacity for innovative research, this is not surprising. Canadian firms also report significant joint R&D activities with partners in Latin American countries.

Manufacturing-related activities are frequently cited in Canadian firms' collaborations with Chinese organizations. Nearly half (47%) of their manufacturing collaboration is with partners from China. China is the second largest producer of pharmaceutical ingredients and generic drugs in terms of value after the US (Yusuf et al., 2007), and Chinese firms are moving into the biotechnology field (Frew et al., 2008). Chinese firms can leverage cost-effective manufacturing in partnerships with foreign collaborators.

Canadian health biotechnology firms' contract research activities are particularly strong with Indian organizations versus with other southern countries. A total of 43% of Canadian firms' collaboration in contract research is with Indian firms and organizations. This fits well with previous studies that show Indian contract research organizations to be leveraging strengths in areas of synthetic chemistry and bioinformatics to offer foreign partners cost-effective investigations in India (Frew et al., 2007; Kumar et al., 2004).
‘Using supplies’ has a higher relative representation in Canadian health biotechnology firms’ collaborations in Latin American countries than in their collaborations with partners in other developing countries. About 75% of Canadian firms’ collaboration initiatives involving this activity are with partners in Latin American countries. The relatively high emphasis on ‘using supplies’ in collaboration with Latin America may reflect initiatives to harness the continent’s terrestrial biodiversity.

This study’s findings suggest that Canadian health biotechnology firms may be leveraging the special strengths of their southern partners in collaborations. This reflects the active role collaborators from developing countries have in the partnerships, and suggests that they are not simply on the receiving end of these alliances.

4.4.4 Initiating collaboration

In this survey, I asked Canadian health biotechnology firms to indicate who initiated their collaborations with partners from developing countries. The results reveal that the partnerships are almost always initiated by the partnering firms themselves. Over half of the collaborations (52% of the north-south collaboration initiatives) were initiated by Canadian firms only, and over a quarter (29% of the collaboration initiatives) were initiated jointly by Canadian and developing
countries partners. About 12% of the north-south collaboration initiatives were initiated by partners from southern countries.

The survey responses did not indicate diaspora communities or expatriates as playing a role in helping to set up the partnerships: only 1 out of 82 collaborations credited expatriates as helping to initiate the collaboration. No collaborations at all were initiated by international organizations.

What is notable is that the collaborations seem to have emerged without much assistance from governmental agencies in Canada or in developing countries – only 7 out of 82 collaboration initiatives received government help in establishing their collaboration. Previous research has suggested that a major challenge faced by Canadian biotechnology firms in penetrating emerging markets is a lack of support in establishing initial linkages with potential partners (Taylor et al., 2007). Many firms are likely to be timid in approaching collaborators in far away countries for partnership building. Canadian and other southern governments are in a position to raise awareness of the potential benefits of north-south S&T collaboration and to facilitate introductions. However, the role of public agencies such as ministries of trade or foreign affairs, in both the Canada and in developing countries, has been limited in nature thus far.
4.4.5 Outcomes of collaboration

Canadian health biotechnology firms were asked to specify any output from the north-south collaborations they reported in the survey. The data indicate that these partnerships are productive (Figure 5) as almost all of the collaborations (90%) report some form of shared output. More than a quarter (29%) of the collaborations have joint products in the pipeline, and 15% of the collaborations already have joint products in the market. This reflects a strong product focus. Joint patenting is, however, rare, with only 4% of the collaborations reporting joint patents as an output of collaboration.

Figure 5. Joint output in Canadian health biotechnology firms’ north-south collaborations
A few Canadian firms indicated that the collaboration with southern partners has led to ‘other’ forms of joint outcomes (9%). These included, for example, entering into distribution agreements and beginning clinical phase studies. Thus, north-south collaboration can be important to firms in achieving milestones in the drug development process.

The limited joint patenting may be due to that most Canadian health biotechnology firms are likely taking their first steps in north-south partnerships. It is possible that there will be more joint patenting as partners become more familiar with one another and collaborations progress.

As the collaborations seem to be young, they are unlikely to have already led to significant increases in revenues. In order to see whether there are any differences between Canadian firms that are involved in north-south collaboration versus those that are not, I compared the financial information of those publicly listed Canadian health biotechnology firms that reported having north-south collaborations with those public firms that did not have such partnerships (Table 2).
Table 2. Canadian health biotechnology public firms: 2007 financial data

<table>
<thead>
<tr>
<th>Financial benchmark</th>
<th>Firms with north-south collaborations (US$ millions)</th>
<th>Firms without north-south collaborations (US$ millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average total assets</td>
<td>33.6</td>
<td>40.4</td>
</tr>
<tr>
<td>Average R&amp;D expenditure</td>
<td>11.9</td>
<td>15.5</td>
</tr>
<tr>
<td>Average total revenues</td>
<td>16.3</td>
<td>4.4</td>
</tr>
</tbody>
</table>

Source: FP Advisor

Both the average total assets and R&D expenditures were similar between public firms that have been involved in north-south collaboration and those that have not. However, the average total revenues of firms that have north-south collaboration are nearly four times higher than those firms not involved in such partnerships. Even after removing the top revenue earner from the group that has north-south collaborations, the adjusted average total revenue is double that of the other group. Thus, the data show that Canadian public health biotechnology firms involved in north-south collaborations generate higher revenues than those that are not. However, since my data are limited, I cannot attribute the companies’ increased revenues to their north-south collaboration. An alternative explanation for the numbers in Table 2 could be that the firms with the highest revenues are the most outward looking.
4.5 Summary

The survey casts light on the current extent and characteristics of collaboration between Canadian health biotechnology firms and partners in developing countries. The results provide a baseline that future studies in this area can compare findings to. However, a survey methodology does not allow for in-depth examination of the dynamics involved in collaboration. Case study research can enable better understanding of these processes. In the subsequent chapters I discuss the results of case study research on Canada-Brazil and Canada-India collaboration in health biotechnology.
Chapter 5

Canada-Brazil collaboration in health biotechnology

5.1 Introduction

Canada formally signed a bilateral agreement for cooperation in science, technology and innovation with Brazil in 2008. As part of the agreement, the Canadian federal government dedicated CDN$ 1.5 million to be spread over two years to foster joint S&T projects with Brazil (DFAIT website a). The Canada-Brazil bilateral agreement aims to encourage greater partnership between the two countries in areas of mutual interest including renewable energy and information and communications technology. Biotechnology and pharmaceuticals are also included as areas of interest for promoting Canada-Brazil S&T collaboration, but it is not clear to what degree these areas are emphasized. In August 2010, six Canada-Brazil projects were selected to receive joint funding for further development under this initiative, and only one of these projects is in the life sciences sector (ISTPCanada website b).

Canada is beginning to show interest towards the strengths that Brazil is cultivating in S&T. In recent years, Brazil has been growing domestic capacity in science-intensive fields, including in health biotechnology. Brazil ranks third among developing countries (behind China and India) in terms of international peer-reviewed scientific publications; the country published 16,285 scientific papers in this field between the years 1996 and 2009 (Thorsteinsdóttir et al., in
press). In comparison to other developing countries also building capacity in health biotechnology, Brazil’s scientific publications in the area are published in relatively high-impact journals (Thorsteinsdóttir et al., 2006). Furthermore, Brazilian health biotechnology firms are noted to be taking their first steps in pursuing innovation (Ferrer et al., 2004; Rezaie et al., 2008). These shifts are garnering the attention of not only science policymakers in Canada, but also in several other developed countries, including the US, Japan, Germany, France and other countries of the European Union; these countries are working to strengthen their S&T links with Brazil (Boekholt et al., 2009; Bound, 2008). A number of northern nations have had decades of experience working with Brazilian institutions in high technology fields, and they are looking at ways by which to further deepen their relationship (Bound, 2008). In contrast, as will be further explored in subsequent sections in this chapter, Canada has only begun exploring S&T partnership, including in health biotechnology, with Brazil recently. As a result, there is lack of understanding of how to best craft public policies and strategies by which to successfully promote Canada-Brazil S&T collaboration. By presenting results of case study research on Canada-Brazil collaboration in health biotechnology, this chapter aims to begin addressing this gap in knowledge.

I first examine the historical relationship between Canada and Brazil, primarily focusing on their political and economic ties. The discussion then shifts to examining policies put in place by Canadian and Brazilian organizations to
facilitate S&T interactions between the two countries. I present the results of the scientometric examination of Canada-Brazil scientific co-publications in health biotechnology, specifically, the extent of research collaboration, its patterns over time and key institutions involved in cooperation in Canada and in Brazil. I then present results of the mapping survey pertaining to Canada-Brazil entrepreneurial collaboration and discussed them briefly. The main focus of this chapter is findings from the case study research on Canada-Brazil health biotechnology collaboration projects, both research and entrepreneurial. I discuss reasons for the collaboration, impediments encountered and any outcomes achieved. In the final section, I summarize key findings of the case study.

5.2 The Canada-Brazil relationship over the years

Before discussing Canada-Brazil collaboration in health biotechnology, it is useful to have an overview of the historical, political and economic ties between the two countries. Such background provides context with which to understand why policies for promoting bilateral S&T cooperation have been rather slow in being implemented, and also the role S&T partnership can play in giving a boost to the overall Canada-Brazil relationship.

Canada’s ties with Brazil began well over a century ago in the 19th century, when the two countries began trading Canadian cod and Brazilian coffee. Canada’s first trade mission to Brazil landed in 1866. At the turn of the 20th century, Canada-Brazil relations were centered on the activities of Brascan, a Toronto-
incorporated firm, whose technology was critical in laying down the early public tramway and electrical infrastructure in the Brazilian cities of Sao Paulo and Rio de Janeiro. Brascal’s Serro do Mar project (1924-44) built the major hydroelectricity stations supporting the Sao Paulo-Rio de Janeiro electric grids. Brascal was Canada’s largest overseas corporation in the early 20th century. Brazilians were employed in numerous industries running on electricity, and Canadian investors profited from holdings in Brascal (Hester, 2005; Ogelsby, 1976). Despite these initial positive outcomes, Canada-Brazil economic ties were damaged greatly by the political turmoil that engulfed Brazil in the latter half of the 20th century.

In the mid-1950s, Brazilian economic growth was dependent on a state-led model financed with foreign debt. Increasing financial stresses and political infighting culminated in a military coup in 1964 that received the support of the US (Hirst, 2005; Wiarda, 2000). The military regime that came into power began to turn inward. Economic nationalism and political oppression made it difficult for foreign firms such as Brascal to continue to operate in Brazil (Ogelsby, 1976). The Canadian shareholders sold their shares in Brascal to the Brazilian government in 1978. During the early 1970s, Brazil represented 10% of Canada’s investment abroad, and this fell to 2% by the end of the decade as firms began to withdraw (Daudelin, 2002). Brazil’s military dictatorship and economic stagnation were blows to the Canada-Brazil commercial relationship.
Conditions to invest in Brazil had become too volatile, and Canadians stayed away from the Latin American country for two decades (Stevenson, 2000).

In the 1990s, Canada made attempts to reinstate ties in Latin America. The NAFTA was concluded in 1994 and negotiations for the Free Trade Agreement of the Americas (FTAA), which aimed to include nations of the western hemisphere, began. Canada pushed for speedy signing of the FTAA because it saw the agreement as a means by which to gain entry into Latin American markets. Brazil, on the other hand, tried to slow down the FTAA negotiations as it wanted time to settle economic matters at home and strengthen its position in southern markets before it was ready to bargain with northern nations. Efforts towards the FTAA ultimately came to a standstill, and Canada and Brazil were not able to rekindle a relationship (Daudelin, 2002; Hester, 2005; Rochlin, 1994).

By the early 2000s, not only did Canada and Brazil have limited ties with one another, but their relations split further as a result of trade disputes regarding their respective aircraft manufacturing firms. Over the years, Canada’s Bombardier and Brazil’s Embraer had become competitors for the regional jet market. The Canadian and Brazilian governments had sponsored the development of their respective firms, and neither was willing to let their firm lose. Canada and then Brazil brought the Bombardier-Embraer case to the World Trade Organization (WTO) over subsidies each had provided their firms. The conflict carried over to other aspects of the Canada-Brazil relationship. When
Canada tried to form an investment cooperation agreement with Brazil, a high-ranking Brazilian minister refused to sign the agreement, citing the Bombardier-Embraer issue. Many Brazilians came to believe that when the Canadian government banned Brazilian beef exports indicating suspicion of Mad Cow disease in 2001, it was in retaliation over the Bombardier-Embraer clash (Daudelin, 2002; Goldstein & McGuire, 2004; Hester, 2005).

The Brazil-Canada relationship certainly had a promising start, but the linkages at the beginning were mainly commercial in nature, and a number of historical events succeeded in veering it off course. By the mid-20th century, ties were limited, and by the end of the century, diplomatic and trade relations were strained. However, Brazil’s circumstances in the global economy have undergone major changes recently. The Latin American country has been able to overcome the political instability that it had been engulfed in since the mid-20th century. It has been able to curb high inflation, bring about greater macroeconomic reforms, and it is now the 10th largest economy in the world (The World Bank, 2007). Brazil’s economy is growing at a rate of 5% annually, and is predicted by some experts to overtake Britain and France beyond the year 2014 (The Economist, 2009). Brazil is one of the few countries that was able to regain its footing after the global financial crisis hit (Prideaux, 2009). Canada is beginning to realize that it simply cannot afford to ignore the trade and investment opportunities an emerging Brazil presents.
Interestingly, in recent years, Brazil has become a notable source of foreign direct investment into Canada; Brazilian investments into Canada are now larger than Canadian investments into Brazil (DFAIT website b). This is a far cry from the situation during the time when Brascan operated. Also, as the Bombardier/Embraer case suggests, the nature of relations between Brazil and Canada in technology and business fields has altered remarkably over the years. In some S&T fields, Brazil is able to compete head on with northern counterparts with homegrown technology; it can no longer be viewed as only being a recipient of technology from abroad. The previous Brazilian government of Lula da Silva emphasized S&T development, and this is likely to continue under the current president, Dilma Rousseff (Petherick, 2010). Despite holding different stances on other political and economic matters, fostering scientific activities and technological development is an area both Brazil and Canada are keen on. Daudelin (2007) suggests that focusing on matters of mutual interest may be a way for Canada and Brazil to revive their bilateral ties. Encouraging cooperation in S&T fields, including in health biotechnology, can be part of the strategy for Canada and Brazil to expand the breadth of their bilateral relationship. Increasing the scope of relations in this manner can maintain bilateral ties in the face of unexpected events. It would also bring greater relevancy to the overall bilateral relationship.
5.3 Government interest and public policy support

In this section, I outline various public programs the Brazilian and the Canadian governments have instituted to promote links with each other in S&T areas. First, I describe some of the Brazilian institutions involved in supporting S&T linkages with northern nations and their specific initiatives with regards to Canada.

The Brazilian government has emphasized collaboration with international partners in S&T only in recent years. The aim is, firstly, to encourage greater international ties in S&T, and secondly, to promote a more organized approach amongst various Brazilian federal and state agencies in forming foreign linkages. However, Brazilian policymakers interviewed for this project readily admitted that linkages between various domestic agencies are not smooth.

At the federal level, the Brazilian Ministry of Science and Technology works with the Brazilian Ministry of Foreign Affairs in determining Brazil’s direction in terms of international R&D cooperation. The main policy directive regarding foreign collaboration is outlined in the National Science and Technology Action Plan 2007-2010. The very first of the 21 action lines of the action plan stresses the importance of international S&T collaboration. According to this central policy document, Brazil’s aim is to revitalize and consolidate international cooperation with the emphasis on strategic areas for the development of the country. Brazil allocated about $ 50 million towards furthering the international cooperation targets in the period between 2007 and 2010 (Boekholt et al., 2009).
The Brazilian government understands that strengthening its S&T base is critical for the overall progress and development of the country. As a result, a concern of Brazilian policymakers is to be able to link international collaboration initiatives to S&T and innovation related objectives at home (e.g., to improve domestic knowledge and technology base) and to social development goals (e.g., to achieve greater equality in Brazil). However, actual mechanisms by which to make the links and the means by which to measure impacts remain unclear at this time.

The Brazilian government has prioritized policy instruments to boost south-south collaboration in science, technology and innovation. It particularly prioritizes other Latin American countries and Portuguese-speaking countries in Africa, although other emerging economies such as India and South Africa are also a focus (Saenz et al., in press). A strong driver behind south-south collaboration is ideological motives for the development of other southern regions (Marcano Gonzalez, 2006). However, promoting collaboration with northern countries is also specified by the Brazilian international S&T agenda. Brazil is promoting collaboration initiatives with developed nations including the US, Japan, and countries of the EU. Brazil has signed various S&T memoranda of understanding with France, Germany, Spain and Portugal (Boekholt et al., 2009).
Although Canada is not named specifically in the Brazilian S&T action plan, interviews with Brazilian policymakers reveal that Brazil is attempting to craft policy initiatives to promote partnerships in S&T with Canada. Previously, scholars found that colonial ties encouraged S&T collaboration (Melon et al., 2009; Moed et al., 1991; Nagtegaal & de Bruin, 1994). However, Brazilian policymakers interviewed indicated that they wanted to pursue deeper S&T links with institutions in Canada, a country that was never a colonial power. Brazilian policymakers are interested in diversifying their ties with northern countries, and they perceive Canadian institutions to be capable of greater compromise in negotiations and agreements than many other northern nations.

The Brazilian Ministry of Education’s Coordenação de Aperfeiçoamento de Pessoal de Nível Superior or Coordination for the Improvement of Higher Education Personnel (CAPES) allocates funding for top-ranking Brazilian scholars to conduct aspects of their training in leading research groups in northern countries, including Canada. CAPES is the body in the Ministry of Education that is responsible for evaluating university-level programs in Brazil. It conducts extensive reviews of undergraduate and graduate level programs, which serve as guidelines for funding distribution. It works to increase expertise of Brazilian students and researchers in science and engineering fields, including in the area of biomedical science. CAPES is interested in forging formal agreements between Brazilian and Canadian universities to facilitate student and faculty exchanges.
The Brazilian Ministry of Science and Technology’s CNPq is the science funding agency at the federal level. CNPq entered into an agreement with CIHR to provide joint funding for Brazilian and Canadian investigators working on projects in health research together. CIHR and CNPq are interested in exchange frameworks whereby Brazilian researchers can work alongside and learn from knowledgeable Canadian colleagues.

Fundação de Amapro à Pesquisa do Estado de São Paulo or Foundation for Research Support of the State of Sao Paulo (FAPESP) is the research support foundation for the Brazilian state of Sao Paulo. A number of Brazilian states have counterpart funding agencies, but FAPESP has been particularly active in organizing and supporting S&T projects, including in the field of biotechnology. FAPESP provides financing not only to academic research in the Brazilian state of Sao Paulo, but also encourages R&D activities in Brazilian firms. The state agency is especially interested in boosting public-private linkages. International Science & Technology Partnerships Canada (ISTPCanada), the Canadian agency which delivers Canada’s International Science & Technology Partnerships Program, signed a memorandum of understanding with FAPESP in 2009 to support Canada-Sao Paulo collaborative R&D projects. ISTPCanada will support the Canadian partners and FAPESP will support Brazilian partners from the state of Sao Paulo (FAPESP website). FAPESP and ISTPCanada are co-funding the six S&T projects mentioned at the beginning of this chapter.
In order to be competitive in a globalizing world, Brazilian entrepreneurs realize that they have to first be comfortable and then adept at conducting business with foreign firms. ApexBrasil, the Brazilian Trade and Investment Promotion Agency, was formed to help Brazilian firms achieve these goals. ApexBrasil does focus specifically on encouraging ties between Brazilian and Canadian firms, including those working in biotechnology. One of ApexBrasil’s main activities is to organize periodic trade shows where Brazilian high technology firms can meet and get to know Canadian counterparts.

I now turn to discuss policies and programs that Canada has implemented to encourage S&T collaboration with Brazil. As discussed earlier in this chapter, the bilateral S&T agreement signed between the governments of Canada and Brazil in 2008 explicitly seeks to strengthen collaboration between Brazilian and Canadian academics as well as firms in high technology fields, including in the biotechnology and pharmaceutical area. It is the main mechanism through which the two countries can promote mutual R&D in health biotechnology. Funds committed towards promoting Canada-Brazil bilateral S&T collaboration, however, are relatively low. Currently Canada has contributed CDN$ 1.5 million over two years towards the joint initiative with Brazil (DFAIT website a). This amount is less than what Canada has allocated for either China or India. As in Brazil, Canada’s S&T affairs are determined in a decentralized manner. Several ministries and departments at the federal and provincial levels
coordinate S&T-related matters, including international S&T policy. At the federal level, DFAIT plays a major role in shaping Canada’s international S&T policy. It is ultimately accountable for the Canada-Brazil bilateral S&T agreement. DFAIT informally works with other federal science-based departments and agencies, including federal funding agencies and the IDRC, through the Interdepartmental Network on International Science and Technology (INIST) committee.

DFAIT’s trade commissioners and S&T counselors are based throughout Canada and internationally, including in Brazil. They provide Canadian companies as well as the research community with information and tools about conducting business abroad. In Brazil, Canadian trade commissioners are based in the cities of Brasilia and Sao Paulo. DFAIT’s Going Global program is designed to support Canadians with non-research expenses such as international travel and accommodation in their endeavours to identify foreign partners and form collaboration initiatives with them (DFAIT website c). Some Canadian entrepreneurs reported applying for funds from this program to explore business opportunities in the health biotechnology field in Brazil. However, the funds for Going Global are not specifically targeted for fostering ties with emerging economies and developing countries. As a result, the funding is limited.

Canada is interested in promoting technological innovation to address health issues faced in developing countries. In its 2008 federal budget, the government of Canada committed CDN$ 225 million over five years to the Development
Innovation Fund to address global health issues. The Development Innovation Fund will be delivered by the agency, Grand Challenges Canada, which is working with the IDRC and the CIHR. Grand Challenges Canada aims to identify critical barriers, which if removed, would help solve an important health problem in the developing world (Grand Challenges Canada website). The agency seeks to support projects that have a health biotechnology focus and address health concerns in southern countries. Projects can originate from Canadian and developing countries institutions, but Grand Challenges Canada does not specifically foster Canada’s collaboration with any particular southern country.

The above discussion suggests that although both Brazil and Canada have made moves towards making north-south S&T collaboration a policy priority, the programs they have may not be targeted to encourage mutual links with each other and specifically in the field of health biotechnology. Also, it is not clear whether the funding amounts Brazil and Canada have dedicated towards promoting their bilateral collaboration is sufficient to encourage sustained ties.

Interview data reveal that Brazil is interested in working with international collaborators based on principles of mutual interest and reciprocity. In the words of one Brazilian policymaker,
“Brazil is no more interested in unequal [relations]. It wants to have a relationship as if Brazil was a developed country. Brazilians don’t want aid. We don’t want technology transfer – we want collaboration.”

Brazil is deeply interested in international S&T partnerships, and its government is renewing or forging ties with northern, emerging and developing countries. Brazilian policymakers have expectations of north-south S&T collaboration; they expect long-term strategic S&T ties to help strengthen the local knowledge and technology base, they expect the partnerships to help them address their social and economic development goals, and they expect to be treated as equals in collaborations. It is not clear to what extent Canadian public policy is working to address these expectations.

In the next sections, I examine health biotechnology collaboration between partnering Brazilian and Canadian academics and entrepreneurs. Greater understanding of these partnerships can provide better insight into how to create a policy environment that is supportive of Canada-Brazil collaboration in this field.
5.4 Mapping Canada-Brazil collaboration in health biotechnology

5.4.1 Mapping research collaboration

The frequency of research collaboration between Canada and Brazil in health biotechnology was gauged. As discussed in chapter 3, co-publications of Canadian and Brazilian authors in this field were used as a proxy for research collaboration.

Figure 6 presents levels of Canada-Brazil co-authored scientific papers in health biotechnology in the period 1993-2004. These data were derived by Science-Metrix from the database SCI Expanded. During this time period, Canadian and Brazilian colleagues jointly published a total of 110 scientific papers in international peer-reviewed journals. The figure suggests that Canada-Brazil co-publications are on a rising trend.
Analysis of Canada-Brazil co-authored papers in health biotechnology extracted by Science-Metrix from the Scopus database examining reveals that 344 such papers were published between 1994 and 2009. Canada-China co-publications in health biotechnology during this period were more than three times greater; based on data derived from Scopus, Canadian and Chinese academics published 1,166 health biotechnology papers between 1994 and 2009 (Thorsteinsdóttir et al., in press). However, it appears that the level of Canadian scientists’ co-publications with Brazilian colleagues in health biotechnology is on par with their co-publications with peers from some other developed countries. For instance, between 1994 and 2009, there were 338 co-publications between Canadian and Israeli researchers in health biotechnology.
Brazil is a country that publishes extensively in health biotechnology with international collaboration; Thorsteinsdóttir et al. (2006) report that about half of its health biotechnology papers are published with external partners. Figure 7 shows the levels of co-authored papers Brazil has published with its top ten most frequent northern collaborators. Canada ranks as Brazil’s fifth most frequent northern collaborator in health biotechnology.

I examined institutions in Canada and Brazil where co-publications originated. This analysis is based on scientometric data derived from the SCI Expanded database. Authors’ institutions of origin include universities, public research
institutions, hospitals and firms in Brazil and Canada. The vast majority of the co-authorships originate from public sector institutions. Researchers from two firms – one Canadian and one Brazilian – have authored Canada-Brazil joint health biotechnology papers.

In Canada, scientists in 35 universities, public research institutions, hospitals and firms were found to have jointly published scientific papers with Brazilian partners. McGill University (Montreal, Canada) was the institution in Canada that had the highest number of co-authorships with Brazilian scientists. One-third of Canadian partners of the Canada-Brazil health biotechnology co-authorships originated from institutions based in the province of Quebec. Apart from McGill University, these included Université de Montréal, Université Laval, Université de Sherbrooke.

In Brazil, scientists in 32 universities, public research institutions, hospitals and firms were found to have collaborated with colleagues in Canada. The University of Sao Paulo was the institution in Brazil that had the largest number of health biotechnology co-publications with Canadian scientists. The State University of Campinas and the Federal University of Sao Paulo, also based in the Brazilian state of Sao Paulo, ranked high among institutions whose researchers have published with Canadian colleagues.
The state of Sao Paulo in Brazil has played an active role in encouraging capacity building and research in science and technology fields, including in biomedical sciences. Since 1989, state law has dictated that 1% of Sao Paulo’s tax revenue be transferred to the state’s research funding agency, FAPESP. Sustained dedicated research funding has enabled higher education and public research institutions in the state of Sao Paulo to develop strengths in fields such as health biotechnology. The expertise built as a result of these efforts is also facilitating Brazilian scientists to work with Canadian colleagues.

5.4.2 Mapping firm collaboration

Results from the survey to map Canadian health biotechnology firms’ collaboration with partners in developing countries show that their linkages with Brazilian firms are low at this point in time (see Chapter 4). Another study where Brazilian health biotechnology firms were surveyed about their collaborations reiterates the low frequency of Canada-Brazil entrepreneurial links (Melon et al., 2009). The relative infancy of the Brazilian health biotechnology private sector may be one reason for the low level of Canada-Brazil firm linkages.

Brazilian companies working in health biotechnology are noted to have strong linkages with other countries in Latin America. Research shows they have south-south entrepreneurial collaborations with partners in Colombia, Chile, Paraguay, Argentina and Cuba (Saenz et al., in press; Thorsteinsdóttir et al., 2010). In
chapter 4 of this dissertation, the data show that Canadian health biotechnology firms are interested in forming ties with firms in a number of Latin American countries. One way Canadian firms can continue to expand their presence in Latin America is by entering into alliances with Brazilian partners and leveraging their regional networks. Similarly, Brazilian firms can use partnerships with Canadian firms to connect to northern business networks.

5.5 Canada-Brazil research collaboration in health biotechnology

In this section, I present findings from interviewing Canadian and Brazilian research collaborators regarding their partnerships. Examples of Canada-Brazil research collaboration projects examined in this project include studying the natural history of Human Papillomavirus (HPV) infection and its relationship to cervical cancer, determining genetic profiles of multidrug resistant Salmonella enterica in public hospitals of Rio de Janeiro, studying enzymes of the Schistosoma mansoni parasite, identifying genes implicated in head and neck cancer, and comparison of allele frequencies in Latin American and North American indigenous communities. I also examine collaborators’ main motivations for entering into partnership, the challenges they have faced, and outcomes of the joint work.
5.5.1 Reasons for collaboration

Research expertise

When specifying reasons for collaboration, scientists from both Brazil and Canada placed the largest emphasis on accessing expertise. The stress on accessing specialized expertise was stronger from the Brazilian side than the Canadian side. All of the Brazilian scientists interviewed pointed to accessing the latest research techniques and methodologies in use in Canadian laboratories as being the primary reason for embarking on partnerships with investigators in Canada. For instance, a Brazilian geneticist went to Canada as a research fellow and spent time with a Canadian cancer genetics research group to train in the molecular cytogenetic method, Comparative Genomic Hybridization, in the late 1990s. The method was actively being used in research laboratories in North America. The Brazilian researcher transferred the technique to his home institution and conducted research on head and neck carcinoma in local Brazilian patients with Brazilian as well as Canadian colleagues.

Around the same time, a Canadian molecular biologist was invited by a Brazilian colleague to help train his research staff in confocal microscopy techniques and help set up the technology in the Brazilian laboratory. The live optical imaging enabled by confocal microscopy enabled the Brazilian research group to work

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4 In this dissertation, I have used the pronoun ‘he’ and the possessive pronoun ‘his’ to refer to all interviewees, male or female. I have done this to protect interviewees’ confidentiality.
with Canadian colleagues in tracking protein traffic in the human body’s cholinergic system, which is implicated in Alzheimer’s disease. Thus, north-south collaboration is a way for Brazilian scientists to keep their knowledge up-to-date with advances taking place in leading research groups in the world. Without constant upgrading in novel techniques, it will be difficult for Brazilian scientists to participate in dialogue with the international research community let alone contribute to the rapidly advancing health biotechnology field.

Canadians also stressed access to expertise as a motivation for their collaboration. Three-quarters of Canadian scientists interviewed for the Canada-Brazil health biotechnology collaboration case study stressed the importance of clinical expertise of Brazilian research teams as being a key motivation for entering into partnership with them. Canadian researchers were aware that they may be able to access and study valuable patient samples in Brazil. One reason for this is that certain diseases may have a higher prevalence in Brazil than in other countries. Brazilian investigators serve as gatekeepers to this special resource. They pointed to the presence of trust in local physician-patient relationships as being important in recruitment to participate in clinical research. In contrast, it is becoming harder to recruit and retain patients in clinical research in Canada due to increased privacy concerns (Willison, 2003).

In Canada-Brazil research projects that have a clinical component, Brazilian clinical teams serve the role of ‘culture broker’; they help Canadian investigators
determine which patient groups should be selected, which Brazilian field sites to work at, and which medical teams to partner with. Brazilian clinical teams help Canadian scientists to navigate the Brazilian cultural context, and to adapt study methodologies to the local environment. Canadian investigators credit their Brazilian clinical partners’ insight into local cultural and social factors. This input increases the interpretive value of any laboratory test performed. A Canadian scientist explains:

“If you don’t have the [local] knowledge, you make certain assumptions… and [the illness] may or may not be occurring [that way]. You have to learn about how [the local clinical teams] do it – their book-keeping, their follow-up. We learn that. We learn the impact of the disease on everyday lives, how it impedes the way to be productive. That gives a sense of the broader dimension of disease implications…”

Without the intellectual input of Brazilian clinical researchers, it is difficult for scientific teams to initiate and conduct their studies as well as to analyze results.

Findings from the case study research reveal that Brazilian and Canadian collaborators initiate partnership with each other to access expertise that they would not be able to access locally. Scientists from Brazil cannot be said to bring fewer or less valuable contributions to collaborative projects than their Canadian
peers. Rather, the two sides bring different types of expertise into partnerships and both types of input are necessary for successful completion of joint projects.

**Funding**

Half of the Brazilian scientists interviewed for this study expressed that they found partnering with Canadian research groups could increase their chances of success in peer-review processes, including grant competitions. This was an incentive for them to enter into north-south partnerships with Canadian colleagues.

Brazilian researchers partner with Canadian scientists in order to prepare and submit grant applications to international funding competitions. The US National Institutes of Health RO1 grants aim to fund research projects that pursue bold ideas in the health field, and international groups are eligible to apply for these grants. However, competition is steep; the success rate is about 7% (Mandel & Vessell, 2008; National Institutes of Health website). The Brazilian collaborator of a Canada-Brazil joint project that was successful in an international funding contest commented:

“I think for [the partner] being in Canada, it was the best situation for someone in Brazil that wants to do a large study. He was there and he got the NIH grant. In
other words, if I myself or even [the Canadian partner] in Brazil, if we write a NIH grant, we would not be able to get it. The fact that he was there I think helped.”

Brazilian scientists do not consider applying to international funding agencies for grants on their own to be an easy task; international peer review committees may not be familiar with their scientific record and endeavours, or they may even harbour biases against applications from scientific communities they have little awareness of. Brazilian researchers feel, however, that if they are associated with reputable partners, including Canadian teams from well-known universities, review committees may look more favourably towards their joint applications.

Cooperation with Canadian scientists is important for Brazilian researchers’ success in domestic funding competitions as well. An important aim of FAPESP is to improve the quality of research done by Brazilian investigators. One way FAPESP works towards this goal is that it encourages Brazilian researchers to form ties to world leaders in their fields, often in northern countries. It gives funding priority to projects in which Brazilian researchers demonstrate they will involve colleagues from research groups based in northern countries. Canadian scientist interviewed for this project attested that on a number of occasions Brazilian researchers approached them looking for partnership opportunities because such associations were viewed as being critical in advancing their local academic career. Four Canadian scientists interviewed felt that their collaboration with Brazilian colleagues helped the Brazilians to build their careers
locally. However, they were unsure of how well their collaboration was perceived by their own peer community at home in Canada.

Results of the case study research suggest that Brazilian scientists do not enter into collaboration with Canadian colleagues to be able to access the northern parties' funding sources. Rather, the reputational effects conferred by their ties to Canadian partners are likely to improve Brazilian researchers' chances of obtaining joint funding from international as well as their own funding from domestic agencies.

**Research talent**

In more than half of the Canada-Brazil research collaboration cases examined in this study, graduate student training was noted to be a major component of the collaborative endeavour. In five instances of partnership examined, the Canadian and Brazilian collaborators first met each other during their advanced studies. Some met when they were on exchange programs as graduate students or postdoctoral fellows. In other instances, they met when one researcher mentored the other, and this relationship grew into that of collaborators over time. It seems that a training environment plays a core role in the initiation of Canada-Brazil research collaboration in health biotechnology.
In this research, I found that Canadian scientists adhere to long-term partnerships with Brazilian colleagues because the collaboration enables them to evaluate and recruit doctoral and post-doctoral students for their research groups. In several cases Brazilian students who Canadian researchers got to know through their Brazilian partner were later recruited to carry out further work in the Canadian scientists' laboratories. One Canadian researcher credits his long-term Brazilian collaborator for introducing him to well-trained, talented Brazilian students. He says,

“[My partner] did provide me with a number of excellent students. He has been very very generous with that. He was evaluating the students, training them, and then he sent me the best of them. I had a good supply of very highly trained personnel. I gained – we gained as a country a lot from that.”

In recent years, Canadian universities have been seeing the numbers of domestic students pursuing research degrees in science and engineering fields decrease. Decline in public funding available to pursue research in S&T fields in Canada as well as brain drain to the US may be among factors leading to the decline (Williams, 2007). Collaboration with emerging economies scientists can help to make up for this deficit. It is through their partnership that Canadian researchers have the opportunity to work with Brazilian students in their partner’s lab, get to know the young investigators and assess their abilities. This prepares
the ground for taking on Brazilian research talent to help them further projects in their own laboratory.

There is the risk that research collaboration between Canada and Brazil can lead to brain drain from the south to the north. Two of the researchers interviewed on the Canadian side for the project were in fact Brazilian émigrés to Canada. However, both of these scientists stressed that they maintain their professional linkages with past Brazilian colleagues, and continue to collaborate on research projects with them. They feel that by holding positions at Canadian universities they have been able to contribute to Brazilian scientists – for instance, by acting as a bridge between the Canadian and Brazilian research communities – in a way that is valuable for both parties.

### 5.5.2 Challenges of collaboration

#### Lack of funding

The most significant challenge to Canada-Brazil research collaboration is lack of funding for the joint research. The majority of the Canada-Brazil teams – all but two – examined in this research did not receive any dedicated funding for their collaborative work. Partners work on joint projects by diverting resources from other operating grants they have. This puts stress on the partnership as any fluctuation on either of the partners’ funding can jeopardize the collaborative effort.
One Canada-Brazil collaborating team did receive support from the CIHR-CNPq program that was mentioned in section 5.3. This program provided travel grants for collaborating investigators to visit each other’s institutions. However, at the time this project was being carried out, the CIHR-CNPq program was under renegotiation and therefore stalled. A Brazilian researcher expressed concern that the application process for the CIHR-CNPq program was much too bureaucratic. According to him, the timelines whereby the Canadian and the Brazilian funding agencies made their decisions differed, and this made coordinating collaborative research activities difficult. Another issue that a Canadian scientist pointed out about the CIHR-CNPq funding mechanism is that while it funds principal investigators on both sides to travel to their partner’s laboratory, there is no provision for graduate students from Canada and from Brazil to go on short exchanges. It is hard to transfer technical expertise and knowledge between Canadian and Brazilian research groups when their graduate students are not able to travel to each other’s laboratories.

Canadian and Brazilian scientists are also eligible to apply for funding under the ISTPCanada program. However, the ISTPCanada initiative makes firm involvement on both the Canadian and the Brazilian sides mandatory in order for researchers to access its funding. Canadian scientists interviewed believe that the criterion for including firms in research partnerships would discourage many Canada-Brazil collaborating academics from applying. One Canadian scientist commented:
“It is damned difficult to include companies with this. Companies are special because their goals are different. Their goal is money. If there is no money involved, only basic research, they don’t care about it. Having companies complicates very much the process. [Research funding] should not be restricted to group with industry. It could be a possibility, but not strict prerequisite.”

Industry-academia relationships can be complicated as parties have highly different goals, and the long-term sustainability of such partnerships is uncertain (Niosi, 2000). A program that aims to support these types of relationships may not appropriately encourage basic research collaboration, and important externalities of scientific partnership will not be realized.

Lack of awareness of Intellectual Property Rights (IPR) issues

A third of the Brazilian experts interviewed for this study note that Brazilian universities and public research institutions they are affiliated are only beginning to gain awareness of IPR and technology transfer related matters. They feel that a lack of understanding of such issues can put them in a vulnerable position in partnerships with northern collaborators who have greater experience in this respect. Three Canadian scientists interviewed also raised the issue that difference in attitudes with their Brazilian colleagues regarding IPR can make
negotiations in partnerships difficult, breed mistrust among collaborators and bring partnerships to a premature end.

The majority of the Canada-Brazil research collaboration projects studied in this project were focused on furthering basic scientific knowledge. However, apart from one project, the collaborators did not rule out the potential for the research to yield practical results – for instance, the development of a novel diagnostic or therapeutic. Traditionally, the Brazilian scientific community was suspicious of private sector interests, believing their role to be seeking knowledge independent of external commercial pressures. Brazilian interviewees in this study perceive that this is an attitude that still persists among many Brazilian researchers, but younger generations of scientists are beginning to feel differently about the issues. Despite growing interest in engaging on projects that have commercial potential, Brazilian scientists lack expertise in filing patent applications and negotiating terms of agreement with external partners. Technology transfer offices in universities and public research institutions are responsible for assisting faculty members to file, manage and license patents, draw contracts and support negotiations. However, technology transfer offices in Brazil are deficient in experienced human resources. One Brazilian researcher expressed his frustration with the technology transfer unit at his institution in the following manner:
“They don’t know what to do basically… they have no clue. [For] the one patent I am responsible for, these guys have no clue whatsoever what they have to do to [license] it… They have no clue. They have no people.”

In this particular instance, the Brazilian researcher lost confidence in the technology transfer experts at his home institution, and turned to his northern partner’s university to file a patent for his invention with the US Patent and Trademark Office. If a Brazilian researcher is allied to a northern institution through a partnership arrangement and he files a patent through it, the northern institution and not the Brazilian researcher’s home institution will garner any potential commercial gains on the technology.

The findings of this study question to what degree Brazilian technology transfer units have the expertise to support Brazilian researchers in their interactions with northern partners in collaborative projects with commercial potential. Canadian scientists interviewed in this study perceive intellectual property managers in Canadian universities and public research institutions to have sufficient experience in supporting them in their dealings with foreign collaborators. Three Canadian interviewees commented that the weak support their Brazilian partners received can negatively impact collaborative projects. There exists the risk that without institutional support, Brazilian collaborators’ expectations of the partnership may not be fully expressed or gauged by their northern partners. This can lead to confusion and conflict between partners, making it difficult to move
forward with the project. Furthermore, Canadian interviewees admitted to being uncomfortable about their negotiations with Brazilian colleagues. This is because they felt that, due to the lack of support they got from their home institutions regarding IPR issues, Brazilian researchers often asked less from partnerships than they were entitled to.

5.5.3 Impacts of collaboration

Increased scientific output

About half of the Brazilian researchers and half of the Canadian researchers interviewed indicated that their collaboration helped them to publish a larger number of scholarly papers than they would have been able to do on their own. A Brazilian researcher explained:

“[In science], the currency is papers published. And if we work together we have the possibility of increasing publications on both sides. I could publish more with this interaction than if I were working without it. This is for sure. Because it speeds things up… So there are two or three or four [colleagues] working – two in one side and two on the other. Speeds up. You get more results.”

Increasing the number of publications on their curriculum vitae helps Brazilian as well as Canadian scientists to apply for further grants and to be considered for
academic promotions. A Canada-Brazil team that examined the epidemiology and pathology of HPV published 54 papers over a partnership that spanned over three decades. Another Canadian and Brazilian duo investigated lipid mediators in asthma for the same length of time and published 37 papers together. Two other teams of Canada-Brazil collaborators published about 10 papers each over the course of a five-year partnership.

Some scientific papers resulting from Canada-Brazil research collaboration have been published in prestigious international journals including the *New England Journal of Medicine* (impact factor 47.1) and the *Journal of the American Medical Association* (impact factor 28.9). Internal appraisal and critique among the Canada-Brazil collaborators before submitting to peer review by the journals can help to maintain high quality of research. Furthermore, Brazilian researchers, whose first language is Portuguese, acknowledge that working in English, the main language of communication in international science, can be challenging. They rely on Canadian colleagues to assist them in revising manuscripts before submitting them to international journals. Canadian scientists expressed that they spend considerable effort in assisting Brazilian partners with manuscripts. Brazilian science funding agencies – such as FAPESP at the state level and CNPq at the federal level – view Brazilian scientists publishing in international journals in the English language favourably in their grant review processes. For Brazilian researchers to publish work in English and in international journals is
important not only to improve their visibility in the global scientific community, but also to be successful professionally in the local setting.

**Network development**

In almost all of the Canada-Brazil research collaboration projects examined, the partnerships provided Canadian and Brazilian scientists the opportunity to get to know further researchers in their partner’s local scientific community, and expand professional contacts in the partner’s country.

Collaborating scientists from the Canadian and Brazilian sides stressed personal chemistry between partners as being important in nurturing partnership. A Canadian scientist commented:

“[If] you are going to go on board with someone for a study that is going to last, you have got to be able to call this person a beer-drinking buddy. There has to be affinity between the colleagues.”

Canada-Brazil health biotechnology collaboration is hardly ever formed between researchers who have never met face-to-face at least once. Initial face-to-face contact and socialization are critical to increase trust between partners. Long-term collaborators begin their interaction on informal discussion and small-scale projects in order to build sustained communication and trust before embarking on
more substantial joint work that requires greater finances to be invested. Trust continues to build with graduate and post-graduate visits between the two laboratories. As the partnership deepens and trust is cemented, scientists introduce their foreign collaborators to local peers who are interested in similar research questions.

Professional contacts made through personal introductions as well as student exchanges aid in the formation of cross-border networks. The following is a comment by a Canadian scientist regarding network building as a result of his partnerships in Brazil over three decades:

“Now I have four generations of students [in Brazil]. I’m an old man, you know – I’ve got four generations. I worked with some people, collaborated with some people that trained some people and so on. [They] are scattered all over Brazil. I could see count at 20 I would say.”

This Canadian researcher has cultivated relationships with Brazilian colleagues in academia as well as in industry. The networks are valuable to both sides because they are a spring-board from which to identify and form further collaborations beyond the initial linkages. To search for and choose a suitable partner is a complex process and recommendations from a hub of trusted local collaborators help scientists to explore new work relationships in a foreign
scientific community. By building a trusted network of partners, scientists can better benefit from the quality of their collaborators’ scientific base.

**Spillovers for industry**

Research collaboration between Canadian and Brazilian scientists in health biotechnology can lead to outcomes that are important for industry. The activities in two cases of research collaboration examined in this dissertation had implications for private sector actors.

In the first instance, a Canadian academic relied on the expertise of a research group from a Brazilian university for a project of interest to a Quebec-based firm. The Canadian scientist first got to know his Brazilian colleagues through an academic collaboration. From this initial work, the Canadian scientist came to know that the Brazilian group had specialized expertise in producing substrate for tracking proteins, and could provide cost-effective labour. He realized this would be of value to the firm he was affiliated with. The company was developing an enzyme replacement therapy for a genetic disorder, and looking for a way to track its therapeutic in patients. As a result of his facilitation, the Brazilian research group entered into a collaborative agreement with the Canadian firm. Based on technology that was jointly developed, scientists at the Canadian firm and the Brazilian research group filed for a joint patent. Ultimately, the firm decided to take a different direction with their technology, and the collaboration
with the Brazilian research group cooled. However, the Canadian and Brazilian scientists still maintain informal ties and discussion. This example reveals that expertise resident in Brazilian universities and research institutions can be of interest to Canadian health biotechnology firms in furthering their projects. Personal contacts made through research collaboration are key in getting to know about these competencies.

Infrastructure established by Canada-Brazil research collaboration projects can provide firms with the foundation to carry out application oriented studies. The case of the Ludwig-McGill cohort study provides evidence of this. Canadian investigators from McGill University (Montreal, Canada) obtained funding to study the natural history of HPV infection and cervical cancer in women from Sao Paulo, Brazil, along with Brazilian researchers at the Ludwig Institute (Sao Paulo, Brazil). The Canada-Brazil research team comprised of epidemiologists and virologists. Together they worked towards a number of objectives including measuring the prevalence and incidence of persistent cervical HPV infection in asymptomatic women, testing the hypodissertation that viral burden may be correlated with low- and high- grade lesions, searching for specific human leukocyte antigen alleles or haplotypes associated with HPV persistence and lesion severity.

The Brazilian and Canadian collaborators recruited and trained local clinical staff, installed equipment for molecular biology analyses, and set up cold storage
space for collected samples. The team relied on this infrastructure to conduct a longitudinal study of more than two thousand Brazilian women over five years. The co-publications and presentations resulting from the research garnered the interest of pharmaceutical majors looking to develop prophylactic HPV vaccines. Merck (New Jersey, US) approached the Brazilian side to use the research infrastructure and personnel that was already in place for clinical development of its vaccine candidate. This vaccine is now available worldwide.

5.6 Canada-Brazil entrepreneurial collaboration in health biotechnology

Entrepreneurial collaboration between Canadian and Brazilian firms in health biotechnology has been limited thus far. This may be because the Brazilian health biotechnology private sector is still young and has until recently maintained a focus on the domestic market (Rezaie et al., 2008). However, my research revealed instances of Canada-Brazil entrepreneurial collaboration involving activities such as R&D, clinical trials and marketing. I examined a case where Canadian and Brazilian entrepreneurial partners were gearing up to conduct proof of principle tests for a novel diagnostic technology. I came across instances where Canadian firms and institutions were involved in working with Brazilian partners on later phase clinical trials. Some Brazilian entrepreneurs
were noted to be in early negotiations with Canadian organizations to pursue collaboration.

5.6.1 Reasons for collaboration

Access specialized expertise and novel technologies

Brazilian firms are interested in entering into collaboration with Canadian partners to access what they consider to be world-class technological expertise. Most of the Brazilian entrepreneurs interviewed for this dissertation mentioned this as an important motivator for seeking partners in Canada. The business manager of a Brazilian health biotechnology firm explained that while his firm had capacity to conduct basic research on compounds derived from Brazilian biodiversity, he was interested in approaching Canadian teams to help with pre-clinical animal studies, and for scaling up of the project. A Brazilian venture capitalist cited an example of such an endeavour; his firm helped a local biotechnology firm it had invested in to move some of its development activities to a location near a Canadian university in order to benefit from the knowledge and experience of Canadian experts there. This move was necessary because the local Brazilian incubator involved in supporting the biotechnology firm was still young and did not have the infrastructure or expertise to assist it.

An interviewee at a Brazilian generics firm expressed that such firms have the financial resources to license novel technologies from Canadian sources that can
then be further developed in Brazil. Although there is interest in doing so, the informant felt that the existence of a corporate culture that was averse to risk had prevented the company from taking such a step. On the other hand, in this research I came across a small Brazilian health biotechnology firm, FK Biotecnologia (Porto Alegre, Brazil), with far limited resources than the Brazilian generics company that formed a partnership with the Canadian start up, SpectraDigital (Guelph, Canada), to license novel diagnostic technology from the Canadian firm. SpectraDigital’s diagnostic technology platform uses light-scattering measurements and image processing techniques to allow inexpensive diagnosis of *Plasmodium*, which is the malaria-causing parasite, multidrug resistant tuberculosis bacilli, HIV/AIDS, and various types of tumour cells. These are all diseases of relevance in Brazil and FK Biotecnologia is planning to conduct proof-of-concept studies of the prototype, file local regulatory documents, determine distribution channels, and help bring the Canadian firm’s proprietary technology to the Latin American market. The CEO of FK Biotecnologia hoped that his firm’s investment into what he believed to be a promising Canadian technology would prove to be profitable for both parties in the long run.

**Management expertise**

Brazilian key informants indicate their interest in learning business and management practices from Canadian entrepreneurs as a reason for entering
into collaboration with them. Most of the Brazilian experts interviewed for this study observed that Brazilian entrepreneurs in health biotechnology lacked experience in running a biotechnology business. Canadian entrepreneurs echoed this sentiment as well. An executive of a Canadian biotechnology firm revealed his sentiments regarding his business dealings with his Latin American partner:

“What was common currency for our conversations [in Canada] was completely a foreign language for [them].”

Brazilian key informants considered working side by side with northern entrepreneurs, including from Canada, would be an important avenue by which Brazilian entrepreneurs can improve their management skills.

Conducting business in health biotechnology is mired in uncertainty at all stages of product development. Executives running such ventures have to develop skills necessary to mitigate these risks. They need to chart a business plan for the venture, raise numerous rounds of finances from investors, meet with regulatory authorities and discuss requirements. Development may be jeopardized if a product candidate’s potential is not articulated clearly by firm managers to potential partners, investors and regulatory authorities. In recent years, Brazilian business schools, such as the Fundção Dom Cabral (Belo Horizonte, Brazil), have started specialized courses to train managers in skills required to work in high technology-intensive business sectors, often in collaboration with northern
universities. However, Brazilian interviewees noted that there is no substitute for hands-on mentoring by experienced executives, and this would only be possible through collaborative relationships.

A Brazilian interviewee elaborated on his collaboration with a US biotechnology company. The Brazilian side had negotiated a training component for young Brazilian scientists as part of their collaboration with the US partner. The hope was that the mentorship would help the Brazilian group conduct business dealings with local and international actors with greater confidence. Having an international outlook – that is, seeking to penetrate markets in northern as well as southern countries – is important for emerging economies firms because the domestic market, although increasing in significance, is still not strong enough to support their growth.

When asked why they would be interested in working with Canadian entrepreneurs rather than firm executives from other northern countries, Brazilian interviewees said they perceived Canadians to be trustworthy in their business dealings. Although they regard US firms as being world leaders in the biotechnology field, previous scandals with US groups regarding bio-prospecting (Hathaway, 2004; Rohter, 2007) as well as past political tensions between Brazil and the US (Hirst, 2005) have rendered Brazilian entrepreneurs more wary of US-based teams.
Clinical studies

According to Theirs et al. (2007), the average relative annual growth rate for clinical trial activities was 16% in Brazil. This is not surprising. There are several reasons why northern firms and organizations, including those from Canada, are interested in conducting human clinical studies in Brazil. First, the cost of running clinical trials in Brazil is lower than in developed nations, including Canada. When asked to estimate the cost differential of conducting clinical trials in Brazil versus conducting them in North America, an executive interviewed at a Brazilian clinical research organization (CRO) suggested it was around 30% less expensive. Furthermore, Brazil has a larger patient population than a country such as Canada. Patient recruitment into clinical studies, as well as retention, is reported to be three to six times greater than that achieved in North America (Dainesi & Elkis, 2007). Recruiting a significant patient population in clinical research gives greater statistical power to studies conducted, and enables better understanding of the treatment measure. Also, speedy recruitment can hasten completion of a trial, thereby bringing novel therapies faster to needy patients.

Canadian interviewees reported conducting human clinical trials in Brazil as an important motivation for initiating collaboration with Brazilian partners. Four Canadian firms and organizations had engaged in partnerships that were formed around clinical research activities.
Linkages involving clinical trial activity can take on various forms, and be handled in Brazil by a variety of actors. For instance, the Clinical Trials Group of the National Cancer Institute of Canada (Kingston, Canada), a non-profit organization whose mission is eradication of cancer and enhancing the quality of life of cancer patients, has been carrying out phase 2 and phase 3 clinical trials of cancer therapeutics in Latin American countries, including Brazil, for nearly a decade. The organization works through intermediaries in the US, which recruit Brazilian contract clinical trial organizations (CTO). Brazilian CTOs qualify and select study centres, file ethics review applications, monitor trials, manage data collection, store samples from clinical trials in cold storage and assist in compiling documents for drug regulatory bodies.

The Canadian firm YM Biosciences (Mississauga, Canada) and its Cuban partner, the Centre for Molecular Immunology (CIM) (Havana, Cuba), are conducting global clinical trials of CIM’s anti-cancer therapeutic, Nimotuzumab, an epidermal growth factor receptor targeting humanized monoclonal antibody. They have selected Brazil as one of their trial sites (YM Biosciences website). Eurofarma (Sao Paulo, Brazil), a Brazilian generics pharmaceutical company, is handling the Brazilian clinical trials arm of Nimotuzumab. Eurofarma is contributing finances towards supporting the clinical trials, and assisting in filing regulatory papers with the Brazilian regulatory system, Agência Nacional de Vigilância Sanitária or National Health Surveillance Agency (ANVISA), in exchange for distribution rights for Nimotuzumab in Latin America. As discussed
previously, the Brazilian health biotechnology firm FK Biotecnologia will be organizing clinical studies of its Canadian partner SpectraDigital’s diagnostic technology. FK Biotecnologia believes that the clinical research it will be conducting has the potential to find new applications of the diagnostic technology and improve the range of its applicability. Finally, Merck ran clinical trials for its HPV vaccine in Brazil relying on the research infrastructure that was developed by the Ludwig-McGill cohort study.

5.6.2 Challenges of collaboration

Red tape

Bureaucratic hurdles in Brazil are a significant deterrent to Canada-Brazil firm collaboration in health biotechnology. Every one of the Canadian as well as Brazilian entrepreneurs highlighted inefficiencies in the Brazilian system that interfered in their mutual partnership. Red tape was noted in processes involving import of materials into Brazil, approval times of clinical studies and regulation surrounding biodiversity research.

Two Canadian as well as two Brazilian entrepreneurs interviewed for this dissertation reported the process to import research materials into Brazil to be rife with challenges. A Canadian interviewee who is involved in testing drug candidates in clinical trials in Brazil elaborated upon his experiences:
“It’s damned near impossible to get [test] drugs into the country. To get your research drug imported, it takes forever. I mean regularly in Brazil [we will be] nearly running out of drug because it is sitting somewhere and you can’t get to it. And every time we try to ship, there is some other reason why it is. It’s ANVISA, it’s customs, everything. I’ve got tons of other countries around the world [where we carry out clinical trials] and it’s Brazil that has a problem. When you are doing a clinical trial with a new drug, the initial stocks often have a short shelf life. So they might only be okay for a year. So you get into this situation where it sits six months in customs and by the time you have it through, it has expired.”

Brazilian customs can spend an inordinate amount of time processing chemicals, reagents, spare parts of research equipment and even animal models needed to carry out experiments. This can lead to the destruction of the material, loss of financial investment, and potentially stalling or scrapping of Canada-Brazil joint studies.

A Brazilian and a Canadian interviewee, both of whom are heavily involved in carrying out clinical studies in Brazil, reported the process to gain approval to perform clinical trials to be woefully slow. According to the Canadian interviewee, in Canada CTOs can start enrolling the first patient into the study within three months of sending the study protocol to Canadian regulatory authorities for review. In comparison, in Brazil it can take nearly six months to initiate the trial. Such delays cost client companies time and money. In Brazil, clinical trial
protocols must go through hospital research ethics boards first, then the national research ethics body, Comité Nacional de Ética em Pesquisa or National Ethics Committee (CONEP), and finally the national drug regulatory authority, ANVISA. Rezaie et al. (2008) estimate that decreasing timelines to trial initiation could potentially increase clinical trial opportunities in Brazil by two-fold.

There are considerable hurdles to be faced when Brazilian and foreign teams try to work on joint projects related to Brazil’s biodiversity. An estimated 13% of the world’s biota is believed to be in Brazil (Lewinsohn & Prado, 2005). A number of Brazilian firms working in health biotechnology are attempting to draw from Brazilian natural resources in terms of their initial candidates. For aspects of their research, they are interested in involving northern partners, including those from Canada. However, there are challenges to their working in this area. Laws based on the United Nations CBD framework that Brazil signed in 1992 govern activities related to bio-prospection in the country (Convention of Biological Diversity website). But a number of high profile cases of Brazil’s failing to receive compensation for the use of active ingredients extracted from its biodiversity have led the Brazilian government to toughen its stance on research in this area (Hathaway, 2004). The Council for Management of Genetic Patrimony (cGEN) was created in 2001 under the Brazilian Ministry of Environment to grant permits to scientists seeking to access Brazilian biodiversity for research purposes. Teams carrying out studies in this field must apply for a license. However, a separate license is required to perform research on samples (Younes et al.,
The way the current system operates can create confusion, stagnation and frustration for those involved in research and product development. In order to file patents on processes to obtain native flora and fauna extracts, the law requires that any traditional knowledge used to obtain the material be recognized and compensated (Moreira et al., 2005). Brazilian firm interviewees observed that identifying indigenous communities and determining fair benefit sharing can be difficult.

Brazilian biodiversity can be a significant strength domestic firms can leverage in their collaboration with northern partners. However, at this time the laws surrounding R&D activities in this area lack clarity, and despite the interest of involving northern partners in this area, at this time firms are staying away.

**Lack of awareness**

Key informants interviewed for this project in Brazil as well as in Canada stressed that a main challenge for firms in the two countries seeking to form linkages with each other is that they lack awareness of each other’s sectors. Eight Brazilian interviewees and four Canadian interviewees reported this to be a barrier. Brazilian entrepreneurs in health biotechnology are more familiar with the biotechnology sector in the US and also in Europe. This is not surprising as Brazil has had historical ties to Europe, and the US has been an active influence in Latin America in the latter part of the 20th century. Canada’s retreat in the
1970s from Brazil has left a void in the relationship that is also being felt in this field as well. Canadian policymakers interviewed admit that at this time channels whereby firms on the two sides can get to know each other are weak and intermittent.

In the course of this research, I came across a Brazilian health biotechnology executive who trained in Canada as a doctoral student and then worked for a time in a Canadian biotechnology start up before going back to Brazil to set up his own biotechnology firm. This interviewee indicated that his past experiences and contacts rendered him comfortable navigating the Canadian health biotechnology scene for potential partners. In recent years, his firm has entered into two collaborations with partners in Canada. This example points to the importance of graduate student exchange and research collaboration as one avenue to foster firm linkages between Canada and Brazil in health biotechnology.

5.6.3 Impacts of collaboration

Canada-Brazil entrepreneurial collaboration in health biotechnology is a relatively recent phenomenon. As a result, impacts of collaboration, particularly in terms of product development, are limited. However, in all of the instances of collaboration that were studied in this project, Canadian and Brazilian partners have been able to identify partners that are interested in maintaining ties with for the long-term. In
the cases studied, firm managers met each other through mutual business contacts, middlemen or at international scientific conferences. As it is difficult for Canadian and Brazilian entrepreneurs to meet in the first place, when they meet a partner they feel they can cultivate a long-term relationship with, they try to sustain the linkages.

For Canadian interviewees, developing initial contacts in Latin America can help them identify further linkages with trustworthy partners on the continent. For Brazilian firms, particularly those that offer contract services, long-term ties with Canadian partners are particularly beneficial. As the Brazilian health biotechnology sector is maturing, its firms may not have a well-developed pipeline of products. Brazilian contract firms cannot rely on domestic firms for steady business, and their main clients are northern firms. Sustainable links formed with Canadian organizations present the opportunity for continued contracts and thus viability for these Brazilian companies.

5.7 Summary

Case study research on Canada-Brazil collaboration in health biotechnology reveals that although Canada and Brazil have competed aggressively in some S&T fields in the past, there is potential for mutually beneficial research as well as firm partnerships between the two countries in this area. Trends suggest that
levels of academic collaboration in health biotechnology are increasing over time; however, entrepreneurial collaboration is still weak.

Case study research casts light on the main opportunities, challenges and results of Canada-Brazil health biotechnology collaboration as expressed by scientists and entrepreneurs on both sides. The study shows that Canadian as well as Brazilian sides bring intellectual as well as other assets that are critical to the success of the partnership, both research and entrepreneurial. There are, however, a number of barriers that prevent health biotechnology cooperation between the two countries from reaching its full potential. Interestingly, the challenges are not necessarily between the Canadian and Brazilian partners themselves. Rather the impediments seem to arise due to misalignments between the institutional set up in Canada and in Brazil.

Brazilian policymakers express keen interest in promoting entrepreneurial collaboration with Canada in health biotechnology. However, at this time, channels whereby entrepreneurs from the two countries can meet and get to know of each other’s technology platforms and plans are limited. In the health biotechnology field, academics are known to be mobile between the public and private sectors. This case study shows that Canada-Brazil research collaboration is important in developing social ties between the countries’ scientific communities, and this may extend to forming links between their health biotechnology private sectors as well. However, there need to be mechanisms in
place to improve mutual awareness of Canadian and Brazilian health biotechnology firms, and, at the same time, increase funding to support cooperation in scientific activities. In this research, only one Canada-Brazil research collaboration project received travel support from their respective funding agencies. It proved to be one of the most sustained and productive joint initiatives I studied, catalyzing about two dozen scientific relationships and even entrepreneurial contacts. This highlights that there is considerable role for public policy in Canada and in Brazil to foster collaboration between the two countries in S&T.
Chapter 6

Canada-India collaboration in health biotechnology

6.1 Introduction

Canada signed a bilateral agreement with India in 2005 to encourage collaboration in science, technology and innovation. The Canadian government dedicated funds of $6.75 million over five years towards the initiative (DFAIT website a). Prior to signing the agreement, academics, entrepreneurs and other experts from Canada and India were invited to a conference organized by Canadian government agencies. The workshop participants held discussions and jointly determined priority areas for the initiative: nanoscience and nanomedicine; information and communications technology; sustainable and alternative energy and environmental technologies; earth sciences and disaster management; biotechnology, health research and medical devices (ISTPCanada website a). Thus, research in both health and biotechnology are prioritized as important areas for Canada-India S&T collaboration.

The Canada-India bilateral agreement was negotiated between DFAIT in Canada and the Department of Science and Technology (DST) in India. The Indian counterpart that ISTPCanada works with is Global Innovation and Technology Alliance (GITA). Currently, ISTPCanada and GITA are supporting ten ongoing Canada-India S&T projects, of which five are focused on developing technologies for the improvement of human health (ISTPCanada website a).
India is a country that has witnessed growth in S&T fields in recent years. The strong export performance of its information and communications technologies sector has contributed to the country’s economy (Joseph, 2010). India is also showing strengths in S&T fields such as health biotechnology. Between the years 1996 and 2009, the country published 19,913 health biotechnology scientific papers in international peer-reviewed journals, and ranked second in terms of developing countries publishing in this field (Thorsteinsdóttir et al., in press).

India has an emerging health biotechnology private sector that is garnering the interest of firms in northern countries attracted to the growing Indian market, and is itself seeking northern partners to access lucrative foreign markets (Kumar et al., 2004; Frew et al., 2007). Results from the survey conducted of Canadian health biotechnology firms about their north-south collaborations revealed that their ties to partners with India are strong; after China, Canadian firms’ second most frequent north-south entrepreneurial linkages in health biotechnology are with India (see Chapter 4).

Although the Canadian government is beginning to emphasize S&T bilateral collaboration with India, its initiatives are relatively recent. Greater understanding is needed on how public policy can best cultivate bilateral cooperation between Canada and India in fields such as health biotechnology. This is of increasing importance as Canada’s peer countries compete to gain India’s interest in S&T partnership. More in-depth knowledge of the processes and dynamics involved in the partnerships can help to inform public policy.
In this chapter, I present results from case study research on Canada-India collaboration in health biotechnology. First, I explore the history of the Canada-India relationship and look at key political, economic and S&T issues around their relations. Then I examine the public policy environment to support Canada-India S&T collaboration. I present data from scientometric analysis of Canada-India co-published papers in health biotechnology. I briefly discuss results of the entrepreneurial collaboration mapping survey on Canada-India firm collaboration. The focus of this chapter is findings of case study research on Canada-India research as well as entrepreneurial health biotechnology collaboration projects that were identified for detailed examination. I examine the motivations for Canadian and Indian partners for entering into collaboration, the challenges they encounter in partnership and the impacts that have resulted thus far from the joint projects. In conclusion, I summarize the main themes resulting from the case study research.

6.2 The Canada-India relationship over the years

In this section, I discuss some of the key features of Canada’s and India’s historical, political and economic relations. This provides context to the public policies that have been implemented thus far to promote their bilateral relationship. It also gives a sense of how ties between the two countries are evolving over time.
Canada has had formal ties with India for only about sixty years. It was after India gained independence from Britain in 1947 that Canada decided to pursue deeper relations with the South Asian country. With the Cold War emerging, India was considered to be a potential ally for Canada in South Asia (Donaghy, 2001).

There was another reason for Canada to want to extend links with India. Travels in that part of the world by leading Canadian politicians and decision-makers increased their awareness of the rampant poverty in the region, and India became a primary recipient of Canadian aid - $2 billion over a quarter of a century. Despite this, disagreements between Canada and India on several international affairs issues began to surface over the years. For instance, India considered Canada to be an ‘apologist’ for US foreign policy, while Canada felt India operated on a double standard: it accepted aid from the West, but criticized its policies, and sided with the then Soviet Union in international political matters. Differences in views in this domain began to erode the mutual goodwill that had been created early in the relationship, and when India tested its first nuclear device in 1974, relations came to a complete standstill (Rubinoff, 2002).

The Canadian government had, in 1955, transferred a CIRUS research nuclear reactor to India to secure its loyalty in the Cold War. Canada was and still is a proponent of nuclear non-proliferation, and decided to seek security through membership with NATO (DFAIT websites d and e). India considered the closed hub of five nuclear powers to be unjust and went ahead to develop its own nuclear program (Singh, 1998). In May 1974, India detonated a so-called
‘peaceful’ nuclear device (“Smiling Buddha”) with plutonium extracted from the CIRUS reactor donated by Canada. Canada was devastated that it had unintentionally contributed to India’s building nuclear military capacity. It also felt betrayed by India (Head & Trudeau, 1995; Rubinoff, 2002). Collaboration in nuclear S&T was terminated. Bilateral talks aimed at a compromise were scrapped in 1976, and for nearly the next two decades, Canada-India relations were minimal (Halloran, 2007; Touhey, 2007). Unfortunately, Canada’s distrust of India and neglect of a bilateral relationship with it coincided with a time when the South Asian country began to enter a phase of economic revival.

Building on reforms instituted in the 1980s, the Indian economy began to liberalize radically in the 1990s. Faced with the collapse of the Soviet Union, a key trading partner, and a balance-of-payment crisis, India began to usher in several market-oriented policies to open itself to foreign investment and international trade. Liberalization prompted dramatic economic growth; India went from having a low 3% annual growth rate to averaging economic expansion at the rate of 6-8% annually (Panagariya, 2004; Dobson, 2006). Once thought to be the ‘permanent sick man of Asia’ (Morrison, 1976), India’s accelerated economic growth began to attract the attention of the global community.

Canada noted the shifts taking place in India. The US had already taken steps towards engaging with India (Hathaway, 2001), and in the year 1996, for the first time in a quarter of a century, a Team Canada trade mission made its way to
India. Business deals were signed and politicians on the two sides met. For a while it seemed that Canada-India relations were back on track. However, when India conducted a second series of nuclear tests in 1998, Canada-India ties were derailed again.

India tested five nuclear devices in May 1998 (“Operation Shakti”), and joined the group of nations possessing nuclear strike capabilities (Vajpayee, 1998). The international community, including the US, expressed strong disapproval of these tests. Canada’s condemnation of India’s nuclear tests was particularly vocal. Canada recalled its High Commissioner to India, banned all military exports to India, and cancelled Canadian International Development Agency (CIDA) programs with the country. While other nations, including the US, moved to thaw relations with India, Canada took steps to suspend trade related talks and it employed trade sanctions against India. Economic contracts were jeopardized, and as an act of retaliation, India cut funding to the Shastri Indo-Canadian Institute, a key program aimed at fostering mutual educational and cultural links between the two countries (Kumar & Narain, 2005; Rubinoff, 2002; Touhey, 2007). Relations hit an all-time low. However, as India’s economy continued to show strong growth in this time, Canada realized it could not afford to stay blind to the economic gains partnership with India would bring in the 21st century.

Starting in 2001, Canada began attempts to re-engage with India (DFAIT, 2001). In 2009, Canada and India concluded negotiations on a Nuclear Cooperation
Agreement. As mentioned earlier, in 2005 the two countries signed a bilateral S&T agreement. Additionally, at the 2010 Seoul G20 meeting, the prime ministers of Canada and India announced that the two countries have begun free trade negotiations. The heads of the two countries have formed a joint study group to explore the possibility of a comprehensive economic partnership agreement, one that can lead to a free trade agreement. The target now is to triple their combined annual trade (DFAIT website f).

Canada-India bilateral ties have gone through highs and lows over the years. What began as a relationship where development aid to India played a major role has changed in a dramatic way. The Canadian government now regards India as a priority country with which to build economic and trade relations with. However, the various blows over the years as a result of India’s nuclear ambitions strained ties and links between the Canada and India are not deep. However, collaborative efforts in S&T fields such as health biotechnology, where the two countries have not experienced previous tensions and that can benefit both sides in terms of economic and social gains, can help to nurture the wider relationship.

6.3 Government interest and public policy support

Here I present the public policy instruments the Indian and Canadian governments have put in place to encourage bilateral cooperation in S&T. These initiatives can also have an impact on promoting collaboration in the health biotechnology field.
The prime ministers of Canada and India issued a joint statement expressing their hope to promote mutual S&T cooperation in 2003. This led to a Canada-India S&T mapping study that was commissioned by DFAIT and Industry Canada in 2003-04. As was mentioned in the introduction to this chapter, broad consultations were carried out with Canadian and Indian stakeholders — academics and entrepreneurs — to determine S&T areas where there was potential for fruitful collaboration (Seethapathy & Johnston, 2004). It was important to begin discussions towards a S&T collaboration agreement with face-to-face interactions between Canadian and Indian counterparts. This is because bilateral relations between the two countries had suffered due to past political and economic freezes, and there was need for leaders in the research and business communities from Canada and India to begin to meet and talk to each other.

In 2005, India and Canada signed a bilateral S&T agreement, highlighting the areas of interest identified through joint discussions between the two countries’ scientific and business experts. Canada’s DFAIT and India’s DST are legally responsible for fulfilling the terms and conditions laid out by the bilateral agreement. The DST, at the national level in India, is responsible for overseeing international collaboration activities. It was important for Canada to sign an umbrella S&T agreement with India because India has a centralized system of coordinating S&T; two-thirds of research funding is contributed by the central
government (Boekholt et al., 2009). Once the DST enters into a collaborative agreement, efforts are made to involve Indian institutions and industries with international partners. India already had long-standing S&T agreements with several other northern nations, including the US, the UK, France, Germany, and Japan.

As was mentioned earlier, Canada pledged $6.75 million over five years towards collaborative projects with India, and India has agreed to match funds. For example, the DBT, an Indian funding agency at the state level, has agreed to provide financial support to potential Canadian and Indian partners seeking to work on health biotechnology projects to hold preliminary exploration discussions. As mentioned earlier, the not-for-profit organization, ISTPCanada, was selected in 2007 to implement Canada’s bilateral S&T programs with India. GITA on the Indian side will be working with ISTPCanada. ISTPCanada is ultimately accountable to DFAIT, and GITA to the DST. Being arm’s length organizations, these agencies have greater flexibility when working with foreign partners than the more structured set-up their parent institutions permit. Together, ISTPCanada and GITA’s mandate is to deliver pre-seed funding to Canada-India collaborative S&T projects that are deemed to have commercial potential. There is emphasis on the joint projects to achieve practical goals. A Canadian policymaker made the following comment on criteria for successful applications:
“The science has to be first class. [But] there has to be some identifiable market for the science. Those who are getting funding have to be in a position to ensure that the market needs will be met through applying the fruits of that research…”

It is mandatory for Canada-India research teams applying for joint funding to have firms involved in the collaborative projects. ISTPCanada is also promoting ‘matchmaking services’ to broker introductions between Canadian and Indian firms. According to an Indian key informant interviewed for this dissertation, policy that stresses commercialization in international collaboration seems to be “in fashion” at this time. Although Indian policymakers claim to have the same mind-set with regards to having a firm focus as their Canadian counterparts, it is unclear to what degree the two sides are indeed aligned in their thinking. At least three Indian policymakers expressed the need for a more diversified approach than simply pushing for engagement of private sector partners in Canada and in India. For instance, one Indian interviewee believed that firms would venture on their own initiative to seek international partnerships for activities such as contract services or distribution related projects. However, he felt that programs whereby research communities from Canada and India were supported to learn about each other, to work together and build trust were necessary to encourage collaborative endeavours focused on R&D. As was discussed in the literature review, in high technology fields such as health biotechnology, there is a fine line between basic and applied research; connections that are made in the context of
scientific activities can be carried over by researchers who are mobile between the public and private sector to address industrial problems.

In recent years, the Indian government has significantly increased its research funding. For example, the DST experienced a budget increase from about $260 million in 2003-04 to about $400 million in 2006-07. The DBT’s budget rose from $60.1 million to $124 million in the same period (Singh, 2006). Kapur (2002) argues that India’s success in the IT arena has given the country confidence that it can succeed in high technology fields, and as a result Indian funders are contributing finances in a significant way to support not only domestic science, but also international cooperation. Just as Indian funding agencies are witnessing a surge in their research budgets, Canadian funding agencies are experiencing a decline in their budgets. For example, CIHR, the federal funding agency for health research in Canada was able to fund only 16% of its domestic applicants in 2007 due to resource constraints (Nature, 2008). The decrease in budget is likely to affect the sustainability of Canadian funding agencies’ support to internationally collaborative research activities. In 2005, CIHR and the ICMR, the oldest Indian federal funding body for health research in the country, signed a memorandum of understanding to foster bilateral cooperation in biomedicine. However, for nearly four years after the signing there was no dedicated funding for joint Canada-India research activities. Finally, in 2009, CIHR and ICMR announced the first Canada-India funding opportunity in the area of childhood obesity. The CIHR Hope Scholarship program, which was awarded to fellows
from south Asia, including India, to train under Canadian investigators has
experienced stalls. A Canadian policymaker laments the situation:

“If we had money, we would do interesting things. The number one issue is the
funding. Funding is so limited. That is the crux of the matter. It is uncomfortable
to sit in meetings with developing countries and we cannot do anything. We have
developing countries willing to spend money, but we can’t.”

A Canadian scientist who was invited to attend a meeting between funding
agencies from Canada and India echoes this sentiment. He recalled his
impressions of the meeting:

“[Canada’s] game plan cannot stop by signing of an agreement. There has to be
follow-up. And that is what the Indians asked over and over again at the meeting
where I was. They said, ‘So, this is what we are committing. What is the
Canadian side committing?’ And they were very generous in their commitment,
the Indians. So what can we contribute to that? At the meeting I was, there was
nothing that we could say. I had the impression that the Indians were a little bit
frustrated by our inability to match what they put on the table.”

It seems that there is some tension between Indian and Canadian funding
agencies when it comes to negotiating finances dedicated towards supporting
Canada-India research activities. The hesitancy and foot-dragging from the
Canadian side can have poor consequences for S&T collaboration between Canadian and Indian scientists.

In addition to central government initiatives to promote Canada-India S&T collaboration, Canadian provinces have their own programs to deepen ties with the South Asian country. British Columbia, Ontario and Quebec have strong life sciences clusters (Niosi & Bas, 2001), and their own strategies to support collaborative projects in high technology fields with India. In Canada, the provinces have significant say over charting their S&T course. Such a bottom-up approach has nurtured regional strengths and promoted specializations that give Canada a comparative advantage on the global stage (Niosi, 2005). The ministries of trade and innovation of British Columbia, Ontario and Quebec have set up or are in the process of setting up offices in major Indian cities including New Delhi, Mumbai and Bangalore. This presence can facilitate market research and networking opportunities in India for their firms.

British Columbia, Ontario and Quebec are among the Canadian provinces that are allocating funds towards R&D collaboration with India. British Columbia’s Ministry of Technology, Trade and Economic Development announced $1 million in funding for S&T partnership with India in 2008. These funds are channeled through the ISTPCanada-GITA program to support any successful projects that involve firms and organizations from British Columbia. For instance, in 2009, a project testing a cost-effective rapid diagnostic for HIV, syphilis and herpes
simplex virus 2 by a Canada-India team was successful in the competition co-funded by British Columbia, as one of the team members was a firm from the province (Government of British Columbia website; ISTPCanada website a).

In 2007, at the international BIO conference, the premier of Ontario announced funding of $3 million to promote partnerships between researchers in Ontario and India. Ontario’s Ministry of Research and Innovation’s International Strategic Opportunities Program (ISOP) prioritizes linkages between Ontarians with partners in several countries including India. ISOP funds may be spent on consortia project management, missions to search for and develop links, travel, seminars, conferences and workshops. While the lead applicant must be an Ontario-based not-for-profit organization such as an institution for higher education, other partners may be from the private sector (MRI website).

The budget of Quebec’s MDEIE (Ministry of Economic Development, Innovation and Export or ‘Ministère du Developpement economique, de’innovation, et l’exportation’) for international collaboration has tripled to about $2.5 million. The key countries the province seeks to increase linkages with in Asia are Japan, China and India. Whereas the Canadian federal government as well as the governments of British Columbia and Ontario are emphasizing firm involvement in research links with India, Quebec has a different approach.
“For ISTPCanada, you need to have an industrial partner. For our program that’s not compulsory to have. Sometimes a company is not necessarily needed because you can have good research, you can have good impact maybe on a medium term. That’s why [the Quebec] program is more flexible,”

argues a key informant. The Quebec government seems to be more comfortable in supporting partnerships between Indian and Quebec-based scientists without compelling industry into the mix.

The diversity of the provincial initiatives reveals the enthusiasm and interest in Canada towards collaboration with India. Lack of coordination between the various Canadian programs, however, is challenging for Indian administrators. An Indian policymaker expressed concerns:

“Ontario is putting money into Indian collaboration. So, that is one of the targets. Saskatchewan is interested. Vancouver is coming next year. Everybody is interested in India. That’s another complicated factor also. Every province wants to come in as a province… I think the best way would be make a strategy, come all together and do it. Now you are asking Indians to visit ten countries within one country out of many. And they all want to do it for Ontario or Saskatchewan. That’s not the best [strategy]. They have to grow out of this frame of mind. That’s my opinion.”
Lack of coordination can add administrative burdens for Indian policymakers. For Canada, too, it poses disadvantages. Without policy coordination, initiatives may be unnecessarily duplicated and resources wasted.

This research suggests that Canada is beginning to experiment with a number of instruments by which to strengthen S&T collaboration with India. Indeed, ever since India has been showing strong economic growth, it is being viewed as a “hot partner” in S&T by many northern countries. The financial investment Canada’s peers are making to vie for India’s attention in this regard is significant. Germany, for instance, a country which has had collaboration programs with India for more than three decades, has pledged $7 million annually to encourage student exchanges (Bagchi, 2008). The UK, also a country India has a long history of S&T collaboration with, is committing $12 million with matching funds from India’s DST to foster joint research (Foreign & Commonwealth Office website). In 2009, Australia committed to providing $50 million over five years to stimulate S&T collaboration with India, in addition to the $20 million it allocated in 2006. India has agreed to match Australia’s contribution. The Australia-India Strategic Research Fund places a special focus on biotechnology-related projects (Australian Government website). Whereas other developed countries are lining up to deepen partnership with India in research activities, Canada seems timid in comparison. Funds are being allocated by the federal and various provincial governments in Canada to foster collaboration with India, but these are spread across numerous smaller programs with diverse aims. The dispersion of
limited funds across many initiatives and lack of a coherent policy framework guiding Canada’s programs with regards to S&T collaboration with India may be reasons why Canada is not gaining the attention of Indian policymakers. One policymaker in Canada talked about Canada’s status in India:

“Canada is not their top one priority. And is it in the top five? Sometimes I am not sure of that.”

Another Canadian interviewee expanded on this theme:

“We are competing with a lot of countries. We had favoured status for some time, but already I have been noting a lot of sense of frustration. They will say it very politely. They have all the patience in the world. But Canada… obviously we are running out of time quickly. And one day, you know, if you call an office and they don’t have time for you, they don’t have time. It’s getting there.”

Indian key informants interviewed for this dissertation suggested that they would prefer to work with Canadian policymakers in building S&T cooperation programs than with those from other northern nations. They express feeling comfortable working with counterparts from a country that embraces multiculturalism, and point out that Canada’s lack of a colonial past is a major asset. However, they feel that if India’s preferences and needs in S&T are not being met through
bilateral ties with Canada, they are confident that turning to other eager international partners is very much an option for India now.

6.4 Mapping Canada-India collaboration in health biotechnology

6.4.1 Mapping research collaboration

Levels of Canada-India research collaboration in health biotechnology were evaluated in this study. As discussed in Chapter 3, co-authored health biotechnology publications by Canadian and Indian academics in international peer-reviewed journals can serve as proxy for research collaboration between the two countries.

In Figure 8, levels of Canada-India co-authored health biotechnology scientific papers between the years 1993-2004 are presented. As can be seen in the figure, the level of collaboration between the two countries is low. Overall, Canadian and Indian scientists published just 43 papers in total in this ten-year period. Not only is the number of co-publications low, for example, as compared to Canada-Brazil co-publications in this field during this same period (n=110), the number of Canada-India health biotechnology scientific papers published appears to have remained fairly constant over the years studied.
Figure 8. Levels of Canada-India co-authored papers in health biotechnology, 1993-2004


Source: Author’s presentation of data compiled by Science-Metrix using the SCI Expanded database

Analysis of data extracted by Science-Metrix from the Scopus database examining Canada-India co-authored papers in health biotechnology reveals that 163 such papers were published between the years 1994 and 2009. Canada published about twice as many scientific papers with Brazil during this same time period. Figure 9 shows the levels of co-authored papers India has published with its top ten most frequent northern collaborators. Canada ranks as India’s sixth most frequent northern collaborator in health biotechnology. The US, UK, Germany, Japan and France have all published a greater number of co-authored papers with India in health biotechnology than Canada during the 1994-2009 time period.
This study found that Canada-India co-authored papers primarily originated from scientists working in public sector institutions in both countries. In Canada, scientists from 31 different institutions across the country were found to be collaborating with Indian colleagues through the scientometric analysis. Among these, the Hospital for Sick Children (Toronto, Ontario) had the highest number of partnerships with Indian scientists. It was followed by the University of British Columbia (Vancouver, British Columbia), University of Alberta (Edmonton, Alberta) and McGill University (Montreal, Quebec).
In India, researchers from 24 hospitals, universities and research institutions across the country had collaborations with Canadian colleagues. The All India Institute of Medical Sciences (AIIMS) and institutions of the ICMR were the top Indian institutions collaborating with Canadian scientists. AIIMS in New Delhi is one of the largest teaching hospitals in India (AIIMS website). The ICMR, headquartered in New Delhi, is a key government institution responsible for promoting and carrying out biomedical research to deal with national health priorities (ICMR website). Indian researchers from the CSIR, also with its base in New Delhi, ranked second among Indian institutions in terms of number of co-publications with Canadian colleagues in the health biotechnology field. The CSIR, with its network of labs and institutes throughout India, is a national institution that supports a range of S&T activities, including in biotechnology (CSIR website).

Although the level of Canada-India research collaboration in health biotechnology is low, as evidenced by co-publications between researchers from the two countries in the field, it appears that several, prominent higher education and research institutions in Canada and in India are working with each other.

In the scientometric analysis of Canada-India co-authored scientific papers in health biotechnology, only one co-publication credited a private sector partner from Canada as a co-author. One reason for the low visibility of private partners...
in the scientific papers may be that firms have preferred to keep development programs confidential, particularly early in the joint project.

### 6.4.2 Mapping firm collaboration

As was discussed in Chapter 4, results from the survey on Canadian health biotechnology firms' collaborations in developing countries reveal that Indian partners figure frequently among such linkages. Canadian firms have the second most frequent ties with partners in India among developing countries, and the level of these linkages is close to the level of alliances they have with partners in some northern countries.

In about 80% of the Canada-India collaboration initiatives reported in the survey, the Indian partner is a firm. The remaining 20% of the collaboration initiatives are with Indian universities and public research institutions. This reveals Canada-India cross-border industry-academia relations.

### 6.5 Canada-India research collaboration in health biotechnology

Examples of Canada-India health biotechnology research collaboration projects I studied include characterizing rabies virus species in the Indian subcontinent, studying mechanisms involved in bacterial protein synthesis, examining the genetics of mycobacteria (microorganisms causing tuberculosis and leprosy) as
well as the leishmaniasis-causing parasite. Some of the projects showed strong
inclination towards achieving practical outcomes. Identifying biomarkers for
diagnosis of head and neck cancer and testing bio-mimetic materials to
regenerate damaged ocular tissue were among these. Here I discuss findings
from case study research on collaboration between Canadian and Indian
academics and examine the main reasons for initiating collaboration, barriers
encountered and impacts achieved.

6.5.1 Reasons for collaboration

Complementary scientific strengths

Half of the collaborating Canada-India scientific pairs interviewed for this study
stressed being able to access complementary scientific expertise in order to
address research questions of common interest as the key reason for initiating
their partnership. Scientists took part in collaboration because they needed
specialized expertise to tackle complicated research problems. Research in
health biotechnology is complex; it demands different types of specialist
knowledge. One Indian scientist interviewed explained,

“I didn’t have [colleagues] in India I could interact scientifically… You need to talk
to people who are experts… And they [were] not in India. They [were] outside. I
[needed] to go outside.”
Indian interviewees believed that the Indian science system, although growing rapidly, is still small in comparison to that of other countries, and as a result does not possess all the expertise needed to conduct investigation on complex research issues. A lack of expertise locally leads Indian scientists working in the health biotechnology field to seek out colleagues internationally, including in Canada.

Canadian scientists also collaborate with Indian colleagues whose unique expertise cannot be found locally in Canada, who they feel share common research interests, and who are likely to contribute to the overall success of a research project. The majority of the Canadian investigators I spoke with considered working with Indian peers to be an enriching experience. One Canadian scientist commented,

“There is a large tradition of thinking and meditating in India. Many investigators in my field are deep thinkers, and so they can contribute very much by their reflection.”

Canadian scientists initiate collaboration with Indian researchers when they are not able to locate expertise necessary to grapple with their research questions locally. A Canadian biochemist approached an Indian biophysicist because he could not find in Canada the combination of research expertise and interest the
Indian collaborator possessed. The Canadian researcher’s laboratory is engaged in synthesizing complex polymers, whereas the Indian partner’s laboratory performs biological assays of polymers. By pooling together their different expertise, the two research groups were working on projects to design polymers that may potentially be used in drug and gene delivery. A Canadian collaborator noted,

“Each party brings in their own contributions and merge ideas and know-how. And that is extremely important. Then the total is greater than the sum of the two parts.”

By combining their respective complementary expertise, the two teams achieve synergistic, unique outcomes that neither party would have been able to attain on their own.

**Technology transfer**

In three-quarters of the Canada-India collaboration research projects examined, partnerships with Canadian scientists enabled their Indian colleagues to gain access to the latest research tools and methodologies. One Indian scientist made the following remark:
“I think Canada has tremendous potential from which India can benefit, definitely as far as the technology is concerned. You have the infrastructure, you have the technical know-how, you have the expertise.”

According to Indian scientists, collaboration with Canadian colleagues helps them to keep up-to-date with the most advanced techniques and research methods in use. A Canadian geneticist sent his Indian partner probes his laboratory had developed to perform genetic analyses of the leishmaniasis-causing parasite. Another Canadian microbiologist began his collaboration with an Indian team when the Indians requested that he share a strain of bacteria developed in the Canadian laboratory to study antimicrobial resistance. A Canadian virologist helped transfer molecular diagnostic technology to a laboratory at a research hospital in India for Indian teams to be able to confirm incidence of local rabies cases and measure its epidemiology. A stem cell researcher in Canada donated scaffold technology to a research team in India that the Indian scientists could use in regeneration of limbic tissue for corneal repair of the eye in Indian patients.

Canadian partners interviewed seemed to feel that they were the main contributors in terms of technology in joint Canada-India research projects in health biotechnology. One Canadian researcher interviewed even said that as the Indian collaborators did not contribute in terms of providing technology, they were not considered to be equal partners in the partnership. However, other
Canadian scientists felt differently. Two Canadian investigators expressed that Indian teams were keen to learn, catching up fast and quickly becoming more equal collaborators. Based on his experiences, one of these Canadian scientists explained,

“[The Indians] are benefitting more than we are from the technology… It’s more on the altruistic side of things that we [transfer technology]. But they have great ideas. And now they are very good. So when they learn something here then they can translate this very efficiently in their lab, and then work on their own in different projects.”

Indian research teams use the technology transferred to perform their own research and also to treat local patients. For example, an Indian biochemist came to Canada to learn mass spectrometry molecular diagnostic techniques from a Canadian research group. The Indian scientist aimed to train colleagues and students in these techniques at his institution upon his return to India. The goal of technology transfer in this instance was to utilize the skills learned to diagnose non-communicable diseases such as various types of cancer as well as communicable diseases such as HIV/AIDS in Indian patients.
Research material

Slightly over half of the Canadian scientists interviewed revealed that a main reason for their pursuing collaboration with Indian colleagues was to access valuable biological samples unavailable in Canada. Studying research material from Indian sources enables Canadian investigators to conduct basic and applied research on communicable and non-communicable diseases that affect Canadian patients as well.

I came across a Canadian molecular geneticist who studies tuberculosis (TB) as a disease model for research on immunogenicity. TB poses a threat to some Canadian patient populations. Outbreak of the disease is a serious health challenge in aboriginal communities (Clark et al., 2002). The Canadian researcher relies on his Indian collaborator and local clinical teams to collect patient samples in India, where TB is prevalent; the country accounts for one-fifth of the global TB incident cases (WHO website). Together the Canadian and Indian researchers are examining the role of host genetics in susceptibility to TB. In another instance, a Canadian scientist studying drug resistance in the leishmaniasis-causing parasite relied on his Indian collaborator to collect research material for the joint studies. Drug-resistant leishmaniasis is a health challenge encountered by Canadian soldiers on missions to various endemic countries, including Afghanistan (Keynan et al., 2008). Samples from India are prized because the country’s tremendous human genetic diversity, as well as its
wide ranging social, cultural, economic and environmental conditions provide a rich context to study complex diseases and increase fundamental knowledge in genetics research.

Patient samples from India are important for Canadian investigators to conduct research into chronic illnesses. For example, potential biomarkers to detect various forms of cancer must show validity in large patient populations in order to have clinical significance. An advantage a Canadian investigator had in his collaborative project was that he could access tissue banks at a large Indian hospital where his research partner was on staff to test potential biomarkers for head and neck cancer. The Indian hospital has annual patient traffic five times greater than some of the busiest Canadian hospitals. Thus, the research material in Indian research hospitals that may be accessed through partnership is valuable in diagnostic development in Canada-India health biotechnology projects.

**Cultural affinity**

Half of the Indian scientists interviewed for this dissertation expressed a sense of comfort and ease when working with colleagues from Canada, and cited this as a pull factor in their decision to work with Canadian researchers as opposed to scientists from other northern countries. Most of the Indian scientists I spoke with have had experience working with investigators from several northern nations.
Two of them completed post-doctoral studies in the US before taking up posts at Indian institutions. However, several Indian researchers revealed that they felt Canadian collaborators were unique in their support of their research efforts. One Indian investigator spoke of his experience working with partners from Canada:

“I personally think Canada is a great country. I agree the US has its advantages, but I think Canada is very unique. Canada is so multicultural – this is something I really like here. You don’t feel you are an outsider. I felt that Canada is open to experts from all over the world, which I think is a unique sort of advantage Canada has to offer.”

Canada is a country that has seen waves of immigration over the course of its history and is highly multicultural (Adams, 2007). The collegiality and openness showed by Canadian partners, who are used to working with colleagues from various backgrounds at home, can be a significant social motivator for Indian scientists to choose to work with them. Indian researchers expressed that when it comes to advising their students interested in studying abroad, they prefer to recommend potential future supervisors they believe their students would feel comfortable working with, and as a result, Canadian research teams rank high among their suggestions in terms of study destinations.
6.5.2 Challenges of collaboration

Lack of dedicated funding

All of the Canadian and Indian research pairs studied indicated that lack of dedicated financing towards their joint projects was the main barrier to having sustained collaboration. None of the Canada-India health biotechnology research collaboration projects I looked at were receiving any dedicated financial support for the collaborative project from Canadian or Indian funding agencies. In two cases, the partners got some initial funding from international agencies – the US National Institutes of Health (Bethesda, US) and the International Union Against Cancer (Geneva, Switzerland) – to kick start the collaborative project. But for the most part, Canadian and Indian research partners divert resources from their existing operating grants from domestic sources to keep the collaboration going – that is, assign human resources, support research trips, and purchase equipment. Although resulting co-publications or output acknowledges both the Indian and Canadian funding agencies, the Canadian and Indian scientists consider their joint work to be occurring in a funding vacuum. The collaborative projects receive informal sanction from their respective institutions, but it is not formally recognized.

Non-availability of dedicated funding means that Canadian and Indian scientists have difficulty sustaining their collaborative efforts. Interesting avenues of inquiry
can be closed if one partner or both is unable to secure funding on their end. Without dedicated support for the joint projects, it is difficult for principal investigators to travel and meet face-to-face or support student exchanges between laboratories. These are the main channels through which tacit knowledge is shared between the collaborating research groups. Also, when there is no dedicated funding, scientists are wary of committing themselves fully to the collaborative projects and hold back their efforts and expectations. This can prevent the full potential of the project from being realized.

Further problems related to power asymmetry arise when there is lack of dedicated funding to support Canada-India research partnerships. In recent years, Canadian investigators are finding it increasingly difficult to secure domestic grants. However, their Indian colleagues are beginning to experience a more conducive environment in terms of financial support from domestic funding agencies. As a result, there are instances where the Canadian side comes to collaboration equipped with fewer financial resources than their Indian partners. One Canadian researcher commented:

“[My partner] is much better funded than I am. There is much more money for him from his government than me from my government. Very little money is accessible here in Canada. CIHR says we have got that much millions, but look at the amount of people who apply for it and you will see that for each one very
"little money is available… Frankly, I would be much better supported in my partner’s country than here."

Thus, there may be instances where the Canadian side enters into collaboration with the Indian side in order to gain from the Indian funding environment. Reliance on the Indian partners for financing may mean, however, that although Canadians contribute core technology, their voice regarding the course of the project can be drowned out. A lack of dedicated funding to support Canada-India collaboration can exacerbate power asymmetries between partners. Dealing with the frustration and resentment that arises from such imbalances can lead to volatile, short-lived partnerships.

**Benefit sharing**

In about half of the Canada-India health biotechnology research projects I looked at, the collaborators were interested in pursuing translational aspects of their basic research. Canadian and Indian scientists had different mind-sets regarding working on projects that are applied in nature. Entrepreneurial ambition among Indian academics was weak in the past, but according to Indian interviewees in this research, this is changing. However, the concept of intellectual property rights and technology transfer issues in Indian universities and research institutions is still incipient (WIPO, 2007). On the other hand, Canadian
researchers are confident about pursuing commercialization. A Canadian scientist expanded on his views about translational work:

“My goal is not to have [commercialization]. But if I see the opportunity, I will do this. Because this is something that we have to be responsible for – this creating not only knowledge but creating opportunities, financial opportunities. If it happens [in the Canada-India collaborative work], we will be ready. And we know how to do that because we have done it here for Canadian [projects].”

In contrast to the Indian side, Canadian researchers I spoke with seemed to have more inclination and institutional support from their institutions to pursue practical applications of basic research projects they are engaged in.

In two Canada-India research collaboration cases, the Indian partners showed interest in gaining experience from their Canadian colleagues to explore commercialization paths of results from their joint research. However, one Indian scientist, whose collaboration with his Canadian partner had matured to a level where there was talk among them about filing co-patents and holding early discussions with firms, expressed concern that reliance on Canadian collaborators and Canadian institutions for translational work can be a double-edged sword. While the Indian investigator considered having an experienced Canadian partner to be an asset when thinking about translational possibilities, there existed a real fear that his own as well as his home institution’s relative
inexperience in dealing with technology transfer and intellectual property rights
issues could cost the Indian side in negotiations regarding benefit sharing. The
Indian investigator noted that if he felt that his laboratory was not getting the
credit it deserved, it would severely disrupt the trust that had developed with the
Canadian collaborating team, and would bring the collaboration to an untimely
end.

6.5.3 Impacts of collaboration

Expand knowledge base

Both Canadian and Indian scientific experts believed the main outcome of their
joint projects to be contribution towards advancement of scientific knowledge.
This was an outcome that was expressed in all of the research pairs that were
studied in this project, and the Canadian and the Indian sides converged in their
responses with regards to this theme.

Canadian and Indian researchers felt that collaboration enables them to access
and benefit from research efforts in laboratories in each other’s countries. These
were often specialized endeavours and unique in the world. The opportunity to
express opinions freely, toss ideas around, debate and argue problems as well
as their potential solutions with specialists was considered to be highly valuable.
The interaction was deemed to be intellectually stimulating, and both sides
expressed that it broadened their research interests. Collaboration enabled both parties to see complex research questions from different perspectives and consider many possible ways of solving it.

Collaboration also gives Canadian and Indian researchers a chance to build critical mass of researchers around common questions of interest. With the larger number of students and colleagues on both sides engaged on the same research questions, it is possible to achieve greater progress in exploring the questions and solutions proposed. By putting their efforts together researchers can overcome bottlenecks with greater speed. When they work together, Canadian and Indian research teams are able to increase their publication record on the joint research questions. One scientific pair published 10 co-authored papers in the first five years of their collaboration. Another pair published 5 co-authored papers in the first two years of their partnership. Collaboration appears to have led to research that is of strong quality; papers resulting from Canada-India research partnership were accepted for publication in well-respected, discipline-specific journals. The Canadian and Indian lead investigators involved in these collaborations were pleased with their productivity thus far; the publications are important not only to further build their own career, but also for the advancement of graduate students on the research teams.

Collaboration not only enables Canadian and Indian scientists to resolve research problems, but it can provide the foundation to ask further questions and
open up new lines of inquiry. For one Canadian researcher, his partnership with his Indian collaborator surpassed his expectations. He explained,

“We learned a lot of good applications. We can write a CIHR grant on this area. That is a big advantage. I don’t think without this collaboration I would be able to get that information. So it’s very useful. It helped my research significantly… That basic seed idea is obtained from this particular [collaborative] project.”

The Canadian investigator credited his partnership with his Indian colleague for widening the scope of his own team’s research activities; the data generated from the joint work is the basis for novel research areas his laboratory can take on in the future.

**Training graduate students**

In three-quarters of the Canada-India research collaboration projects I studied, training of graduate students was considered to be an important outcome of the partnership. This was particularly so for the Indian teams. In five of the collaborative projects, Indian students came to train in the Canadian collaborator’s institution. Collaboration enables Indian students to have the opportunity to be exposed to world-class research expertise of Canadian scientists and research groups, and to learn from them. India faces a shortage of advanced level training programs in the biological sciences (Vale & Dell, 2009).
The majority of the Indian researchers I spoke with try to send their graduate students to their Canadian partners’ laboratory to gain practical skills as well as theoretical knowledge. Even if funding channels to enable Indian students to visit a Canadian partner’s laboratory can be difficult to access, Indian scientists try to muster up their own funds to enable brief student visits to Canadian universities and institutions for one or two semesters. With the new knowledge and skills gained from Canadian mentors, Indian students can begin novel research programs at their home institutions and further train local students.

Canadian scientists interviewed expressed the importance of two-way student exchange. Many felt it was imperative that Canadian graduate students have better insight of local conditions when trying to understand complex diseases. Without such awareness, it is difficult to appreciate multi-faceted aspects of risk, prognosis, patient behaviour and treatment. According to Canadian interviewees, Canadian students could become stronger researchers if they spent time working side by side with Indian colleagues and saw the realities faced by patients. Canadian students were considerably less mobile than their Indian counterparts, and only a small number of Canadian graduate students went on exchange to Indian institutions. One reason for this is low availability of funding opportunities to support such visits. Concern was expressed that Canadian students were hesitant to go spend time in developing countries institutions because they perceived this experience would be of less value to future employers than experiences gained in research groups from other northern countries.
A consequence of student training is the forming of interpersonal relationships between Canadian and Indian students. Professional contacts and trusting friendships cemented during training years can have long lasting effects. These are carried forward as students progress in their careers. Some students may join industry in Canada and in India. Personal and professional networks built earlier can form the basis of relationships on which future business deals are made.

Previous Canada-India training experiences were in a number of cases the foundation from which novel collaborations took shape. In three of the Canada-India collaborative projects I looked at, the partnership between the lead investigators could be traced back to their own experiences as trainees or even training experiences of their academic supervisors. Entering into joint projects with long-distance partners who are strangers is considered to be a nerve-wracking prospect for Canadian as well as Indian scientists. Familiarity and trust are important, and training of students and exchange is one way by which to achieve greater social and cognitive closeness between foreign scientific communities. One Indian researcher initiated his Canadian collaboration after his Canadian-Indian mentor, an academic who spent time in India on sabbatical, supported him to find colleagues in Canada. Two researchers who were friends and fellow students in an Indian institution are now actively collaborating after one of the scientists took up a research position at a Canadian university. In another instance, the supervisor of a Canadian academic had completed post-
doctoral work at an Indian research laboratory. This supervisor recommended his Indian colleagues to his student, and the Canadian academic then embarked on joint projects with them. Training of research personnel and associated mobility provides the context whereby greater familiarity and trust can be developed between Canadian and Indian scientific communities. Both sides then have additional opportunities to gauge each other’s research interests, direction, capabilities and mind-set, which can lead to discovering of potential synergies and can deepen ties. Thus, seeds for future collaborations are sown.

**Input into entrepreneurial activities**

Partnering Canadian and Indian scientists were asked if there were any practical implications of their collaborative research. Two of the collaborating pairs reported that results from their research had implications for private sector activities. One team filed a joint patent under the Patent Cooperation Treaty (PCT) for potential biomarkers for head and neck cancers and pre-cancers. In the event that their collaborative research matures and leads to the development of a novel cancer diagnostic, both the Canadian and the Indian investigators have professional contacts with firms in Canada and in India to whom they can license the technology for further scale-up and eventually marketing and distribution. It is interesting to see that as India’s home-grown health biotechnology private sector continues to grow, Indian firms are becoming an important component of commercialization plans.
The research results of another Canada-India team examining transport of macromolecules in blood was garnering interest from biotechnology firms in North America interested in novel drug delivery mechanisms. The Indian partner of this team felt that being allied to a top Canadian university was helpful in his own laboratory’s gaining visibility internationally. The Canadian partner expressed that if the collaboration yielded further results that held commercial promise, the collaborators could consider spinning off a firm based on the joint work. Such a firm could be incorporated in either Canada or India. This suggests that results generated from Canada-India research activities could potentially provide the basis for new firms to be formed. Locating the firm in India would be advantageous in terms of cost. However, technology transfer offices in Canada have greater experience than those in India, and would be better placed to provide advice in spin off formation.

6.6 Canada-India entrepreneurial collaboration in health biotechnology

As discussed in chapter 4, firm collaboration between Canadian and Indian firms working in health biotechnology is relatively active. My research shows Canada-India entrepreneurial collaboration in health biotechnology to be characterized by diverse types of alliances. I examined Canada-India entrepreneurial initiatives involving R&D activities. I studied instances where Canadian and Indian
companies were hired to offer contract services to Indian and Canadian firms respectively. I looked at parent-subsidiary relationships of both Canadian and Indian companies.

6.6.1 Reasons for collaboration

Cost effective development

Nearly all of the Canadian entrepreneurs I spoke with cited accessing cost advantages in India as a critical reason for their linkages with Indian partners. Both large and small Canadian firms are interested in benefitting from cheaper development conditions available there.

Two Canadian firms were observed to have established subsidiaries in India to access low cost R&D. According to Wilkie (2004), Indian scientists earn one-third of what their North American counterparts make. Canadian firms want to take advantage of this cost differential. I found a small Canadian health biotechnology firm had set up a subsidiary in India to perform pre-clinical studies of bacteriophage technology that can potentially be used as anti-infectives against antibiotic-resistant bacteria. Data are exchanged and shared between scientists from the Canadian and Indian sites. In addition to face-to-face meetings, regular emails and conference calls are relied on for exchange and sharing of data between the Canadian and Indian sites. Another Canadian firm also set up a
R&D subsidiary in India. This Indian subsidiary employed about fifty local scientists, but was predicted to expand to about two hundred employees. The Canadian company is not only gaining from cost effective scientific labour in India, but can also benefit from local expertise. Due to the Indian pharmaceutical sector’s strengths in generic drug development, local scientists have experience in pharmaceutical formulation. This is an expertise the Canadian parent is interested in, and there is a likelihood that a greater portion of research activities in this area may be shifted from the Canadian site to the Indian subsidiary in the future.

Canadian firms seek collaborators to help them in performing cost effective clinical testing in India. Two Canadian firms I interviewed as part of my dissertation were actively looking for suitable Indian collaborators in this regard. Padma (2005) estimates that the average cost of a clinical trial in India is nearly half of that in North America. Interviewees from three Canadian firms reported that they are keen to find Indian partners working in the clinical trials arena. They observe that the large, drug-naïve patient population in India allows for faster recruitment than in North America or Europe, which translates to cost savings. Indian firms have engaged tertiary and specialist hospitals and networks of physicians across India for clinical trial management. Those that are looking to attract foreign clients, for example, multinational pharmaceutical companies, are applying for international certification and working to maintain international standards in clinical practice (Frew et al., 2007). The managers of Canadian
firms, however, stress that they have to perform extensive due diligence before signing contracts with Indian firms to ensure financial terms are clearly understood. Healthcare is predominantly privately administered in India (Bajpai & Saraya, 2010), and as such can have expensive overheads. Furthermore, Canadian firms have to make sure that their proprietary technology is protected when working with Indian contract partners.

Canadian firms are further interested in collaborations with Indian firms in order to take advantage of their cheaper production conditions. The cost of manufacturing pharmaceutical/biotechnology products in India can be 70-80% less expensive than in North America (Wilkie, 2004). In this study, I came across a Canada-based custom active pharmaceutical ingredient (API) manufacturer that was able to maintain its global competitiveness in a time of recession because it leveraged the chemical synthesis expertise and low-cost manufacturing of a sister facility in India. By transferring synthesis and manufacturing tasks to the Indian facility, the Canadian firm was able to offer services to its mainly northern clients at competitive rates. Canadian executives warn, however, that thorough checks and oversight are necessary when outsourcing manufacturing work to Indian partners. It is important to make sure Indian firms are using equipment that is up-to-date and follows internationally accepted standards.
Access novel technologies and research talent

Both Canadian and Indian firms indicate interest in scoping for novel technologies and scientific talent in firms, universities and public research institutions in each other’s countries. India signed the WTO Trade Related aspects of Intellectual Property rights (TRIPS) agreement in the year 2005, and there has been pressure on its firms to transition from generics production to innovative product development. In addition to conducting in-house R&D activities, Indian firms can also aim to increase their innovation capacity by accessing novel technologies from foreign, including Canadian, partners.

Interviewing a key informant at a leading Indian generics pharmaceutical company revealed that the firm would be interested in sponsoring activities of research teams at Canadian universities that could add value to projects being undertaken in the company. I identified a case where an Indian generics pharmaceutical firm licensed vaccine technology from a Canadian public research institution. The vaccine technology was developed by Canadian scientists to target intracellular agents responsible for HIV/AIDS, tuberculosis and malaria, as well as cancer cells. According to one of the Canadian scientists who helped develop the technology, normally the Canadian research institution prefers licensing its inventions to Canadian firms. However, in this instance, it made an exception because it was felt that Canadian biotechnology firms were not interested in technology targeting neglected diseases. The Canadian
inventors did not want the technology to remain stuck. They chose to license it to the Indian generics pharmaceutical firm because the Indian company showed enthusiasm about the potential of the technology, was determined to have good capabilities in R&D, and had the financial capacity to afford the license. Unfortunately, after a few years the Indian firm returned the license back to the Canadian research institution, citing change in its R&D direction. The Canadian key informant, however, feels that more sustained interaction between the Canadian inventors of the technology and the Indian research teams after the licensing agreement was signed would have been useful in helping the Indian firm to get the vaccine technology off the ground.

Canadian firms indicated accessing novel technologies and research capabilities in Indian institutions as a reason for entering into partnerships to a lesser degree than Indian firms. However, in my research, I came across an instance where promising technology being developed at an Indian research institution was acquired by a Canadian health biotechnology firm. The Montreal-based firm Ambrilia acquired research talent and anti-prostrate cancer technology from the National Institute for Research in Reproductive Health (Mumbai, India), a public research institution in India. One of the Indian scientists initially working on the technology was recruited by Ambrilia and continued to work on the developing the technology in Canada. The anti-cancer peptide went on to become one of Ambrilia’s flagship products. Canadian firms can know of emerging technologies in Indian universities and research institutions only if their research personnel are
plugged into the local scientific community from early on in the basic research stage. The key informant interviewed at Ambrilia had had long-standing research collaboration with the scientists at the Indian public research institution. He revealed that this experience showed him that scouting for promising technologies and research talent in developing countries can be of interest for Canadian firms. He had hoped to set up a R&D facility in close proximity to the Indian public research institution in order to facilitate knowledge flows between Ambrilia scientists and Indian investigators. This did not come to pass, but it does show the interest some Canadian firms have in engaging in R&D activities with Indian scientists to increase their own innovation potential.

**Strong regulatory environment**

For Indian firms working on novel health biotechnology products, a motivation to work with Canadian partners is to access the strong drug regulatory environment in Canada. Confidence in the regulatory process in Canada is strong; regulatory policies are considered to be transparent and compliance-friendly (Mitchell & Munn-Venn, 2005). However, the same cannot be said for the Indian drug regulatory system. The Drug Controller General of India’s office is underfunded and overburdened with applications. In late 2007, the World Health Organization (WHO) disqualified the Indian drug regulatory body. As a result, Indian firms that had received approvals and clearance from the Drug Controller General of India were barred from supplying the WHO with vaccines. This decision was
overturned in 2009 after a thorough audit by an international team (Pandeya, 2009). Such instances have weakened the confidence of Indian firms in their national drug authority. None of the firms interviewed in India for this dissertation considered it to have the experience to assess novel drug candidates and evaluate first-in-man clinical studies at this time. Thus, Indian firms embarking on new-to-the-world innovation feel the need to look to countries with strong regulatory frameworks to conduct initial assessments of their products.

Drug regulation comprises a number of activities related to different aspects of drug development. These include inspection of production sites and distribution channels, adverse drug reaction monitoring, quality control, oversight regarding drug advertising, and control of clinical drug trials. Drug regulation in Canada is assigned to Health Canada. Indian firm interviewees consider Health Canada, the Canadian drug regulatory authority, to have stronger governance mechanisms as well as greater transparency, and maturity in evaluating novel health products than their agency at home. Piramal Healthcare (Mumbai, India) conducted phase 1 clinical trials of its first proprietary anti-cancer candidate in Canada. These studies were carried out by the Juravinski Cancer Centre (Hamilton, Canada) and under the eye of Canadian regulators. Indian firms for the first time in their histories have novel technologies in their product pipelines, and they are keen that regulators who have the highest standards evaluate these technologies. They are not willing to tarnish the potential of these health
technologies by going through regulatory channels that are still struggling to adhere to effective norms and guidelines.

6.6.2 Challenges of collaboration

Intellectual property rights infringement

Half of the Canadian entrepreneurs I interviewed commented on potential risks they face from inadequate IPR protection when working with partners in India. They worry that as they carry out aspects of R&D, clinical and manufacturing activities in alliance with Indian firms, their proprietary technology and knowledge will not remain protected, and that there is only limited action they can take against such violations. The problem of IPR infringement is compounded by frequent employee turnover in Indian biotechnology firms.

One Canadian entrepreneur expressed grave concerns about some Indian firms’ abilities to keep confidentiality regarding intellectual property. He makes the following observation:

“I am not sure if the [Indian] system can control copies. I hope they can. [When working in emerging economies, Canadian firms] are potentially at risk. Some [Indian] employees [can] leave and they start another company and they start to produce something that is very similar to yours.”
Another Canadian entrepreneur echoed similar sentiments. He commented on the high turnover rate of employees in Indian firms, and also in some Indian subsidiaries of Canadian firms. This made him nervous. In recent years, the Indian pharmaceutical/biotechnology sector has been experiencing rapid growth, and Indian employees have more opportunities available to them than before. This, combined with the lack of trust and loyalty between employees and employers in a still young sector, may be leading to high employee movement in the sector. Extensive traffic of this kind can make it difficult for intellectual property to remain protected in India at this time.

Canadian entrepreneurs feel that without a trusted partner, it can be difficult for Canadian health biotechnology firms to work in the Indian context. According to one interviewee, the best way Canadian companies can protect their proprietary technology is to select a reputable, trustworthy partner. His firm decided to enter into collaboration with an Indian company because the Indian partner had a proven track record of respecting the intellectual property in previous partnerships with multinational pharmaceutical companies, and he himself had professional contacts with some of the executives of the Indian company through prior business dealings. Had this history not existed, the Canadian firm would have been hesitant to sign agreements with the Indian firm.
Canadian firm executives I interviewed acknowledged that intellectual property protection is not easy with working with Indian partners. But they felt that this concern is balanced against the potential impacts the collaborations may bring. One interviewee believed that Canadian firms face somewhat of a paradox when working with partners in India. He commented,

“If you want to be in [this] market, you need to try to give them some of your secrets. That is the risk [Canadian firms] are taking everyday.”

Lack of regulatory alignment

Canadian and Indian firms engaged in collaboration are attempting to take advantage of their comparative advantages to develop health products. The innovation process has become global. For instance, a firm or research institution in one country may carry out basic research on a therapeutic candidate, whereas clinical development and manufacturing may take place in the partner’s jurisdiction. Phase 1 and 2 clinical trials may not be conducted in the same country. However, such globalization of product development adds to the regulatory burden of the firms involved. Lack of alignment between Canada’s and India’s drug regulatory regimes presents a constraint to collaboration between their health biotechnology firms.
Drugs are among the most regulated consumer products. National governments closely monitor all aspects of production and distribution (preclinical testing, clinical trials, manufacturing, marketing, post-marketing surveillance) of drugs in their market. Drug regulators from different countries can have widely different guidelines in terms of these operations. These stem from complex factors: regulators may have undergone diverse evolutionary paths historically, they may be tied to varying political and legal structures in their home countries, they may have unique priorities influencing their decision-making, and they can differ drastically in terms of their human and financial resource allocation (Ratanawijitrasin & Wondemagegnehu, 2002). Drug regulators consider themselves to be the guardians of public health, and as a result require firms working in their jurisdiction to comply by their specific standards (Vogel, 1998). However, when firms from different countries are working on drug development projects together, it can be difficult for them to satisfy divergent requirements of regulators in their home and in their partner’s countries. Partnering firms find themselves having to repeat tests, submit separate applications for the same activities and meet distinctive criteria to comply with the requirements of more than one regulatory agency. Without streamlining between international regulators, collaborating firms, especially small health biotechnology firms with limited funds, can face significant administrative as well as financial stresses.

At this time, neither Canada nor India have taken active steps towards adjusting drug regulatory policies to boost firm collaboration and competitiveness. The
main interaction Health Canada has with the Drug Controller General of India’s office is training programs for the Indian agency’s employees. As Canadian firms deepen their working relationships with Indian partners and they undertake joint product development, lack of regulatory cooperation between their national regulatory systems can impede their ability to integrate activities. If activities carried out in one jurisdiction are disregarded by the regulatory authority of the partner, synergies possible in Canadian and Indian firms collaborating will not be realized.

**Lack of awareness**

Half of the entrepreneurs interviewed in Canada and in India expressed that they lack information about the capabilities and focus areas of Indian and Canadian firms respectively working in the health biotechnology area. There are several reasons why awareness on both sides is low. A study by Melon et al. (2009) showed that north-south entrepreneurial linkages in high technology fields such as health biotechnology seem to follow historical trade relationships. As was discussed earlier in this chapter, trade traffic between Canada and India has been interrupted several times in the past, and this may have contributed to health biotechnology firms on both sides having little knowledge of each other. Several of the Canadian entrepreneurs I spoke with commented that in recent years the number of trade missions to India has increased. But four Canadian firm managers interviewed felt that these have focused on larger Canadian
enterprises and not on small biotechnology firms. A Canadian policymaker acknowledged this. He said,

“A lot of small biotech companies simply do not get on the radar of a trade commissioner. They don’t have a tangible product, they are too small, they are dealing with intellectual property issues that are far too complex for a trade commissioner to sign off on for an export deal.”

Thus, Canadian health biotechnology firms do not receive adequate support from trade commissioners in their exploration of Indian firms.

There is also internal pressure within Canadian firms that prevents them from scoping potential partners in India. Canadian interviewees observed that health biotechnology firms in Canada that are funded by venture capital investors have highly focused milestones they have to meet within strict timelines. Under these circumstances, it can be difficult for Canadian firms to spend time and resources to identify an Indian partner they are able to trust and who fits with their trajectories. One Canadian entrepreneur spoke about the mentality of some Canadian firms:

“So even though [Canadian firms] may be aware of what’s happening in India, there’s underlying pressures that push them in another direction that they may not have control over.”
He believed that even if Canadian entrepreneurs are interested in exploring partnerships with Indian as well as other southern collaborators, they face resistance from their venture capital financiers and scientific advisory boards from doing so. They are left with little room to experiment with north-south collaboration.

6.6.3 Impacts of collaboration

I asked Canadian and Indian firm collaborators about outcomes that their partnership has led to. Their responses suggested that Canada-India entrepreneurial collaboration in health biotechnology can result in a number of positive impacts for the participants involved.

Linkages enable the acquisition of novel technologies and research talent that fuel a company’s growth. This was the case for the Canadian health biotechnology firm, Ambrilia. Successful development of the anti-cancer technology it acquired from an Indian research institution enabled the firm to attract subsequent rounds of domestic financial investment and to continue to build its technology platform. Thus, working with Indian partners can be an opportunity that aids Canadian firms in their growth.
Novel therapeutic leads that Indian companies are beginning to develop provide interesting prospects for contract research organizations in Canada. One Canadian contract clinical trial organization showed keen interest in gaining contracts to study novel therapeutic candidates from Indian and other emerging economies firms. The interviewee at this firm commented,

“I think [the emerging economies] are going to be coming up with agents that are going to be of interest to us. They certainly have been a good opportunity for us to get on early and get involved early with exciting agents.”

New business from emerging economies players is particularly important for Canadian contract research organizations because innovators have traditionally turned to US-based groups over Canadian teams to conduct projects.

Canadian firms, facing the global financial crisis, are increasingly strapped for cash. According to Ernst & Young (2009), more than half of the public Canadian biotechnology firms had less than a year’s worth of financing remaining. I examined one instance where partnership with Indian pharmaceutical firms helped a Canadian health biotechnology firm to weather tough economic times. Equity investment by Piramal Healthcare into the financially struggling Canadian start-up Biosyntech (Montreal, Canada) was able to keep the Canadian firm afloat and preserve jobs in the company. Biosyntech is involved in the development of thermogels for tissue repair and drug delivery. After encountering
difficulty in raising financing from North American venture capitalists, the firm approached one of India’s largest generics pharmaceutical company, Piramal Healthcare, for funding. In exchange for distribution and R&D collaboration agreements, Piramal Healthcare made a CDN$ 6 million investment in the Canadian firm. An interviewee at Biosyntech exclaimed,

“[The Indian partner] saved us! They saved us, that’s incredible.”

Coming from a financially strong position due to generics sales worldwide, and looking to boost its innovation potential, Indian generics pharmaceutical firms have the financial strength and strategic interest to support innovative health biotechnology firms in Canada.

In linking with each other, Canadian and Indian firms can combine and leverage their competitive advantages, and raise their revenues. This is particularly clear in the case where a Canadian active pharmaceutical ingredient manufacturer allied with an Indian generics pharmaceutical company. The Canadian firm brought to the alliance decades’ worth of technical expertise as well as international reputation. The Indian firm provided the possibility of cost effective manufacturing and labour. Together the firms were able to expand their client base (mainly biotechnology firms in northern countries) and provide them with a wider range of services at competitive rates. In just a year’s time, the venture’s revenues increased by 20%. 
An important outcome of Canada-India firm collaboration in the health biotechnology field is that the initial business relationships can provide firms a springboard to explore further opportunities in the partner’s country. An Indian generics pharmaceutical company has, for instance, acquired a Canadian firm. After this initial experience, the Indian company formed R&D alliances with Canadian firms and public research institutions, and it is also engaged in clinical trial activities in Canada. I observed a Canadian firm that had first established a subsidiary in India later forming distribution and then co-development agreements with a local firm. It seems that first steps in building Canada-India ties prompt further exploration by firms into more diverse and more intensive partnerships. Early positive experiences with collaborators can confer greater trust as well as deeper ties in the international partner’s local business community from where new partnerships arise.

6.7 Summary

Although Canada and India have differed significantly in their views on nuclear S&T, case study research shows that there is considerable potential for scientists and entrepreneurs on the two sides to work together in health biotechnology. In recent years, the Canadian government has been trying to boost economic and trade relations with India, and as a result it has been emphasizing firm linkages in S&T fields as well.
Mapping co-publications in this field shows that research collaboration between Canadian and Indian scientists has been limited thus far, and it does not seem to be increasing. However, surveying Canadian health biotechnology firms shows that firm collaboration is quite strong. Results of the case study show that both academic and entrepreneurial collaboration is marked by reciprocity as well as bi-directional flow of knowledge and finances. But there are a number of systemic challenges that prevent Canada-India collaboration in health biotechnology from reaching its potential. Lack of funding for research collaboration is a serious challenge; none of the joint Canada-India research projects examined for this dissertation received funding support from Canadian or Indian funding agencies. Issues regarding IPR protection, and lack of regulatory alignment also impede collaboration. Despite the Canadian government’s emphasis on supporting inter-firm links in S&T areas, it seems that channels whereby Canadian and Indian firms working in the health biotechnology field can meet are weak.

The impacts of Canada-India research and entrepreneurial collaboration in health biotechnology are considerable. Partnership plays a role in increasing the knowledge and productivity of scientists. The joint studies enable scientists to consider and pursue novel lines of inquiry and research. Collaboration enables Canadian and Indian firms to combine and leverage their respective strengths and capabilities in supporting the development and commercialization of therapeutic candidates. Canada’s support for multiculturalism is a draw for Indian scientists and entrepreneurs to seek collaboration with Canadian counterparts.
The social ties and personal contacts that are developed are the basis for future academic and entrepreneurial relationships.
Chapter 7
Canada-emerging economies health biotechnology collaboration explained

The previous chapters presented the findings of the mapping exercises and case studies on Canada’s research and entrepreneurial collaboration with Brazil and India in the field of health biotechnology. In this chapter, I will summarize my main findings and discuss how they relate to the existing literature on north-south S&T collaboration.

I will also propose a model of how to analyze collaboration. I argue that north-south S&T collaboration should be analyzed from the perspective of interactions between partners’ systems of innovation. An interacting innovation systems model of collaboration considers influences of the wider institutional environment in the partners’ countries on the collaboration but draws particular attention to the alignment of the innovation systems in the participating countries. It thereby focuses on how the interaction of innovation systems shape collaboration and innovation resulting from the partnership.

I then discuss what policy implications my study has pointed to, particularly for Canadian policy makers. This discussion is informed both by interviewee suggestions and from analyzing my data through the lens of interactions of systems of innovation. Where appropriate, I review policy initiatives implemented
in other developed nations to encourage collaboration with the emerging economies to learn from their experiences. I consider the limitations of the research and suggest future areas for investigation before concluding the chapter.

7.1 Mapping Canada-emerging economies health biotechnology collaboration

7.1.1 Mapping research collaboration

In my initial review of the literature, it was unclear whether Canadian academics were collaborating with counterparts in the emerging economies in health biotechnology. The few previous studies that had performed analyses on Canada’s research collaboration with southern partners did not necessarily focus on this field, but rather looked at science fields in general. In one instance, the researchers presented their findings in too aggregate a format to be useful to measure the level of Canada-emerging economies' health biotechnology collaboration; the data did not reveal temporal trends in co-publication patterns. Furthermore, all of these studies were out of date.

Considering these limitations in the literature, as part of the first objective of this study, I aimed to map the levels and key characteristics of Canada-emerging economies research collaboration in health biotechnology. To fulfill this aim, I
examined Canada-Brazil and Canada-India co-publications in the field of health biotechnology relying on data extracted by Science-Metrix from the SCI Expanded and Scopus databases.

These data reveal that Canadian scientists do work with colleagues from Brazil and India, and publish papers with them in health biotechnology. Although in the past Canada experienced challenges with Brazil as well as India in S&T areas such as aerospace and nuclear technology at the political level, their scientific communities are not averse to working with each other in the health biotechnology field. The level of their collaboration is, however, low. This is particularly the case in terms of Canadian scientists’ partnerships with Indian researchers. The scientometric analysis in this dissertation shows that Canadian academics in a number of institutions spread out across the country – universities, public research institutions, teaching hospitals – have research linkages with partners in Brazil and India. It is also interesting to note that these linkages are dispersed across numerous institutions in a number of cities in the two emerging economies. This seems to signal the openness of Canadian investigators from various institutions towards health biotechnology collaboration with colleagues originating from diverse institutions in Brazil and India.

According to the scientometric analysis, Canadian researchers have stronger linkages with Brazilian peers than with Indian peers. Based on the results from SCI Expanded, it seems that while co-publications with Brazilian investigators are
on the rise, levels of Canada-India co-authored health biotechnology papers in international peer-reviewed journals do not seem to be increasing. However, results from the Scopus database, which includes examination of more recent co-publications, hint that this trend may be changing and Canada-India research collaboration in health biotechnology may be on the rise. Further detailed research, however, is needed to gain greater insight into this issue.

The scientometric analysis in this dissertation reveals that for both Brazilian and Indian academics, Canada is not the main location in terms of their northern collaborators in health biotechnology research activities. According to the data, Canada is Brazil’s fifth most frequent northern collaborator and India’s sixth most frequent northern collaborator in health biotechnology research. Although, as has been described in chapter 2, Canada has significant strengths in this field, it seems to be attracting the interest of the Brazilian and Indian research communities only to a limited degree. The US, the UK, Germany, France and Japan are among the developed nations Brazilian and Indian academics in health biotechnology have the most frequent partnerships with.

7.1.2 Mapping entrepreneurial collaboration

Previous research has attempted to measure Canadian firms’ international collaboration in biotechnology, and in one case with India specifically. However, these data are out of date, and it does not target the field of health biotechnology
specifically. I aimed to map the levels and overall characteristics of Canada-developing countries entrepreneurial collaboration in health biotechnology as part of the first objective of this study. Analyzing results from surveying Canadian health biotechnology firms about their north-south collaborations was a way by which to address this knowledge gap.

The survey findings reveal that about a quarter of Canadian health biotechnology firms have some form of linkages with developing countries in several global regions. These include Latin America and Caribbean, Sub Saharan Africa, North Africa and the Middle East, South Asia, East Asia and Pacific. However, their main southern partners are in China and India. Although Canadian firms report having numerous collaborative initiatives with partners in several Latin American countries, ties with Brazil at this time appear to be relatively limited.

Research by Melon et al. (2009) surveyed developing countries firms working in the health biotechnology sector, including firms from Brazil and India, and asked them about any south-north partnerships they had. Based on this work, it appears that Brazilian and Indian firms have relatively strong alliances with firms and organizations based in developed nations. Brazilian firms’ main northern firm collaborators are from the US, Germany and France. Indian firms’ main northern firm collaborators are the US and the UK (data obtained from authors). Thus, in terms of the emerging economies’ north-south entrepreneurial collaboration in health biotechnology, Canadian firms are not among their main collaborators.
The data collected by the survey exercises serve as a snapshot of the partnership landscape at a particular point in time. Regrettably, in this dissertation there was no opportunity to collect data that made it possible to evaluate shifts in Canada-developing countries entrepreneurial collaboration over time. Gathering information on a longitudinal basis would provide improved information on whether Canadian firms' collaboration initiatives with developing countries and emerging economies partners are on the rise or whether they are not changing over time. Such data would also enable further comparison between Canadian and other northern countries firms' collaboration with emerging economies partners in health biotechnology.

7.1.3 Summing up mapping results

From the results of this dissertation, it is clear that Canadian academics and entrepreneurs are indeed engaging in collaboration with Brazilian and Indian counterparts. However, a close look at the pattern of research and firm collaboration reveals that partnerships are uneven. Research collaboration is relatively limited with both Brazil and India, particularly in comparison to Canada’s collaboration with China. Several other developed nations have stronger ties with both Brazil and India in terms of research collaboration in health biotechnology. On the entrepreneurial collaboration front, a significant number of Canadian firms reported working with southern partners in health
biotechnology. However, again, Canada’s peers among northern nations have greater ties to both the Brazilian and Indian sectors.

7.2 Research collaboration

7.2.1 Reasons

This study examined Canada-emerging economies research collaboration in health biotechnology. The second research objective outlined in chapter 1 of this dissertation pertained to finding out why Canadian and emerging economies scientists decide to take part in collaborative projects. By studying a number of Canada-Brazil and Canada-India health biotechnology collaborative research projects, it is clear that there are several motivations for the partnerships. North-south research collaboration cannot be described in terms of any single reason; rather, a multitude of motives are involved in their initiation. This suggests that research collaboration between developed and developing countries is not a one-dimensional phenomenon, but is multidimensional and complex.

The main reason cited by Canadian as well as Brazilian and Indian scientists interviewed for entering into collaboration was to access specialized expertise they could not locate at home. In order to complete complex research projects successfully, investigators need to reach out internationally for the requisite specialized skills. Scientists do not possess all the expertise themselves to
address complex, multi-faceted research problems on their own. They need to seek out complementary skills to help solve difficult research challenges. It is noteworthy that Canadian investigators cited reaching out to Brazilian and Indian colleagues to access specialized expertise almost as often as the other way around.

The literature on north-south research collaboration had suggested that a primary motivation for such partnership was for southern scientists to access expertise from the north to compensate for their weak science systems. While this was valid for some of the Canada-Brazil and Canada-India collaborative research projects I examined, it did not feature as centrally as I had expected. My research shows that as Brazil and India are strengthening their indigenous health biotechnology scientific capabilities, northern investigators are taking notice of these developments and seeking southern knowledge and expertise in this S&T field. Some of this knowledge is on local conditions, but there are also pockets of disciplinary expertise in both Brazil and India that Canadian scientists are interested in. The literature on north-south research collaboration has shown that access to expertise is the main motivation for northern scientists' to collaborate with each other. My research supports the notion that access to expertise is equally important as a driver for north-south research collaboration.

Access to research material in the emerging economies was an important reason for Canadian researchers to work with Brazilian and Indian colleagues. Canadian
scientists are interested in studying patient tissue samples and pathogens, as well as indigenous flora and fauna in Brazil and India. This wealth of biological material is not found in Canada; Brazilian and Indian scientists did not express much of an interest in accessing research material in Canada. Local partners in the emerging economies play a critical role as gatekeepers to this resource. Without their support and knowledge of local factors and conditions, it can be challenging for northern researchers to access or interpret the data collected. This is a considerable leverage southern investigators have in partnerships. Possessing interesting research material can enable southern scientists to negotiate technology transfer and opportunities to co-author publications in north-south research partnerships. Some Brazilian and Indian scientists were indeed observed to be indeed doing so. This suggests that emerging economies scientists are not necessarily in a passive role in north-south research collaboration projects. They have considerable voice in how collaborative initiatives are conducted and analyzed.

7.2.2 Challenges

A key research question of this dissertation was: what are the challenges experienced in Canada-emerging economies research collaboration in health biotechnology? This relates to the second objective of this dissertation. Analysis of case study results enabled gaining greater understanding of the impediments
encountered in Canada-emerging economies health biotechnology research collaboration.

According to the literature on north-south research collaboration, asymmetries between northern and southern scientific teams in terms of the resources they have available to them can disrupt their partnerships. The literature regards northern groups to have a more dominant standing in collaboration; that they dictate the direction the research should take, carry out the more conceptual tasks and reap the most significant rewards. In my study of Canada-Brazil and Canada-India research collaboration in health biotechnology, I did not detect such hierarchical relationships between the northern and southern partners. There was little indication that the Canadian, Brazilian and Indian scientists played qualitatively different roles. Both the southern and northern sides made intellectual contributions to the joint projects and also provided material resources to support it.

Even though the findings of this study point to a rather equal collaboration, it is impossible to rule out that Brazilian and Indian scientists are in some cases subordinates to Canadian investigators. It is possible that the Brazilian and Indian scientists I interviewed were too embarrassed to admit that Canadian investigators dominate joint projects. It is difficult to detect passivity among collaborators by applying the interview technique. To elicit authentic opinions from interviewees, it was stressed to them that information communicated in
interviews would be kept confidential; their partners were not privy to opinions expressed. Still, some Brazilian and Indian interviewees were adamant about Canadian colleagues being preferred partners as they had experience working on an equal basis with researchers from various backgrounds in a multicultural setting at home. There is, therefore, reason to believe that the collaboration I studied did not suffer from unequal power relations between the northern and southern participants.

The literature had pointed to inequities in north-south research collaboration, and specifically pointed to the issue of northern partners having greater resources in partnerships being in control of joint projects. However, the funding environment in Canada and the emerging economies studied is shifting: Canada is experiencing declines in research funding while both Brazil and India are seeing increases. Such a trend can cause new forms of inequities in north-south research partnerships, including in fields such as health biotechnology, that were not observed before. This has the potential to cause stresses in collaboration particularly because in the vast majority of collaborative initiatives I looked at, the partners draw from their operational grants to support joint projects. When Canadian scientists come to a partnership with fewer financial resources than the emerging economies side, they can be at risk of being sidelined by southern scientists in important decisions regarding the joint projects, such as determining the direction of the research as well as authorship. This can happen despite
Canadian teams bringing significant knowledge and technical expertise to a collaborative effort.

7.2.3 Outcomes

The second objective of this dissertation was to gain insight into the types of outcomes resulting from Canada-emerging economies research collaboration in health biotechnology. The literature reviewed in chapter 2 claims that while north-south research collaboration in S&T have certainly strengthened research capacity in developing countries, it has not contributed to innovation or industrial applications. The findings of my case study on Canada-Brazil and Canada-India research collaboration in health biotechnology agrees with the literature with respect to the capacity building effects of the collaboration. My findings, however, diverge from the literature with respect to contribution of collaboration to innovation and showed some cases where primarily academic collaboration was contributing to firm innovation in the health biotechnology sector.

Canadian, Brazilian and Indian investigators interviewed for this study considered their collaborative efforts to have resulted in good quality science. Partnership can increase their productivity and highlight novel areas for inquiry. Collaboration contributes to expanding the knowledge base; unique knowledge is produced that neither party would have been able to achieve on their own. Canadian as well as emerging economies scientists regarded this to be the most important
impact of research collaboration. Thus, this finding gives support to the literature that suggests research collaboration can strengthen the quality of science.

Furthermore, graduate students are trained via joint projects where collaborators send their graduate students to each other. Students learn important knowledge and skills from experts in the field, but through research collaboration. Collaboration makes it possible for them to gain exposure to foreign laboratories where they can access new research infrastructure and both codified and tacit knowledge important for their development as researchers. Students also begin building social ties with collaborators and their students. This exposure can give rise to a new generation of research collaboration when students become independent investigators and form their own partnerships with their mentors and colleagues in the partnering country.

Canada-emerging economies research collaboration in health biotechnology results at times in outcomes that are of interest to industry. Methodologies and instrumentation used in Canada-emerging economies research collaboration are adapted by Canadian as well as emerging economies firms to further their own projects. Academic-entrepreneurs, who come to know of specialized expertise of international scientists through their academic collaboration experiences, catalyze research agreements between such research teams and firms. Furthermore, clinical infrastructure created by collaborating scientists attracts the attention of firms in either of their home countries or internationally to conduct
human clinical trials. Finally, in some cases, technologies that are being developed through Canada-emerging economies collaborative research are acquired by firms for further development and commercialization.

It was interesting to see cross-border Canada-emerging economies university-industry linkages in this research, and enthusiasm among interviewees for such partnerships. Emerging economies researchers were keen for the projects they were working on to receive attention from northern firms that have experience with commercialization of novel health technologies. They felt that working with Canadian collaborators would help them access opportunities to encounter northern entrepreneurs. However, while there was interest expressed in these types of ties, Canadian, Brazilian and Indian scientists understand that such links can be difficult to manage. Particularly on the southern side, scientists receive little support from their institutions to help them navigate and negotiate issues including benefit sharing and intellectual property rights with northern partners.

7.3 Entrepreneurial collaboration

7.3.1 Reasons

This dissertation includes a focus on the motivations behind Canada-emerging economies entrepreneurial collaboration in health biotechnology. To meet this research aim, I analyzed data from case study research of Canada-Brazil and
Canada-India health biotechnology entrepreneurial collaboration. I also relied on some findings from surveying Canadian health biotechnology firms about their ties with developing countries.

Gaining access to developing countries markets was the most frequently cited reason for collaboration by Canadian firms. The Brazilian and Indian pharmaceutical markets are growing rapidly, and Canadian firms are interested in exploring them. Southern firms are seeking collaboration with Canadian firms to break into the lucrative North American market. Emerging economies firms seek the marketing expertise, distribution channels and professional networks of Canadian firms in the biotechnology sector to enable them to enter the Canadian as well as the US markets. Local partners are critical for Canadian and emerging economies firms to navigate foreign markets; they help file applications with domestic research ethics boards and regulatory agencies, and to evaluate the local competitive environment.

Both Canadian and emerging economies firms collaborate with each other to access specialized expertise and novel technologies. Indian and Brazilian firms have licensed vaccine and diagnostic technologies that were initially developed by Canadian researchers. They further want to gain access to specialized management expertise and expertise in drug regulation. Canadian health biotechnology firms have also acquired specialized research expertise and technologies from emerging economies. Further, Canadian firms contract cost
effective services of emerging economies partners to solve technical problems and conduct clinical trials. It appears that for both the northern and the southern sides, cooperation gives firms access to a wider range of solutions to technical challenges and, as a result, partnerships are an important means by which to enhance innovation capacities and maintain competitiveness.

Accessing financial resources is another motive for Canadian and emerging economies firms to form partnerships. Many Brazilian and Indian firms rely on a hybrid business model (Frew et al., 2007; Rezaie et al., 2008) where revenues from generics production or contract services are reinvested into R&D for novel health products. Some of these firms, looking to boost their own product pipelines, invest in small Canadian health biotechnology companies that have innovative technologies but are facing financial difficulties. Also, the cost effective R&D services, manufacturing and clinical trials that emerging economies firms are able to provide serve as a financial incentive for northern firms. Brazilian and Indian health biotechnology firms, on the other hand, are interested in risk capital from Canadian venture capital firms. Not only are they interested in gaining funding, but they are keen to access managerial expertise of Canadian venture capital firms.

My examination of motivations for Canada-emerging economies firm collaboration suggests that neither the northern nor the southern sectors are leaders in the relationships. Both sides have strengths and weaknesses, and
they seek collaboration to access expertise and other resources in a partner’s innovation system that complements the particular characteristics of their sector.

7.3.2 Challenges

As discussed in the introductory chapter, an important aim of this dissertation is to look at what factors hinder Canada-emerging economies entrepreneurial collaboration in health biotechnology. This ties to the second objective of my research. There are several factors impeding these associations. Interestingly, firm interviewees in Canada, Brazil and India rarely mentioned problems internal to the partnership itself. Rather, they pointed at challenges posed by the institutional environment in which the collaboration initiatives are embedded. Systemic misalignments between northern and southern institutions pose a barrier for innovation to take place in collaborative initiatives.

My study found that a poorer understanding of intellectual property rights by collaborators from the emerging economies compared with that of their colleagues from Canada can form an obstacle in collaboration. Technology transfer offices played little role in supporting emerging economies scientists in negotiations with Canadian partners. The recurrent comment was they were inexperienced. Due to the lack of institutional support, emerging economies investigators do not always feel their interests are protected in partnerships; there exists a significant concern that their institutions’ inexperience in knowledge
transfer practices will not be able to protect their interests in negotiations with northern partners. Canadian entrepreneurs are also nervous about intellectual property rights issues when working with partners from the emerging economies. A serious challenge they feel in such north-south partnerships is inadequate intellectual property rights protection when working in the emerging economies context. The knowledge imbalance in knowledge transfer practices and intellectual property rights issues between Canadian and emerging economies institutions can lead to uncertainty and mistrust that can ultimately impede technological cooperation between their countries.

A common theme in this study is that national differences in drug regulations make it difficult to carry out R&D across borders. Health biotechnology innovation is becoming increasingly globalized in its scope. Firms were observed to be attempting to carry out different phases of the drug development process with partners in different countries, including in developing countries and emerging economies, which have the expertise to carry out the task in an efficient and cost-effective way. This globalized innovation process, however, can add to the regulatory burden for health biotechnology firms, especially when the technological and administrative requirements of national regulatory systems in the participating countries differ widely. Collaborating firms can find themselves having to repeat tests and submit distinct applications to meet the requirements of numerous regulatory agencies. Due to lack of regulatory alignment, north-
south firm collaboration in health biotechnology can become cumbersome, time-consuming and expensive.

**7.3.3 Outcomes**

The question of what outcomes Canada-emerging economies health biotechnology entrepreneurial collaboration has led to is of interest in this research. It relates to the second objective outlined in chapter 1 of this dissertation. Analyzing the case study data reveals that although Canada-Brazil and Canada-India firm collaboration in this field is a relatively new phenomenon, cooperation has led to a number of impacts for both the northern and the southern participants.

Working with local partners has facilitated the entry of Canadian and emerging economies firms into each other’s markets. Canadian and emerging economies firms have acquired innovative health technologies from institutions in each other’s countries. This has fuelled their growth because subsequently they were able to attract further rounds of investment. Canadian and emerging economies firms have contracted companies in each other’s countries to conduct clinical trials and completed these studies successfully. It is particularly noteworthy that an Indian firm is conducting clinical trials in Canada on its new-to-the-world therapeutics. Considering that India has a reputation of carrying out cost effective clinical trials, it is interesting that the Indian firm’s mistrust of the regulatory
system in India has driven it to carry out the trials in Canada. Thus, Canada-emerging economies entrepreneurial collaboration has been important to firms to achieve critical milestones of the drug development process. There is some empirical evidence that north-south cooperation is leading to increased revenues for participant firms. However, the collaborative initiatives studied are young and there is need for more follow up research in this regard.

While the partnerships are beginning to yield results, a key outcome is that the Canadian sector is gaining greater familiarity with health biotechnology firms in Brazil and India through these collaborations and vice versa. Canada has only recently begun to strengthen trade ties with the two emerging economies and Canadian health biotechnology entrepreneurs admitted having had low awareness of counterparts in the emerging economies. Working with trusted partners is critical, however, when working in the emerging economies as protecting intellectual property rights can be a concern. Similarly, Brazilian and Indian entrepreneurs are also interested in deepening ties with Canadian peers. The initial linkages provide the base from which firms explore further opportunities for cooperation in the partner’s country. Also, collaborative initiatives evolve over time as trust builds; these can deepen from short-term consultancy services to more sophisticated joint venture agreements.

Collaboration can impact the national systems of innovation the collaborators originate from. Outcomes of collaboration, which include new knowledge,
technologies and the formation of academic and entrepreneurial networks across the two countries, have socioeconomic benefits for both systems. However, there are also potential negative consequences of collaboration. There exists the risk that countries with weaker systems of innovation that have fewer linkages among domestic institutions will not be able to absorb all the outcomes of collaboration. They, therefore, do not reap returns from their investment in the collaboration.

Unless collaborative initiatives are under the radar of a number of relevant institutions in local systems of innovation that are closely engaged in each other's activities, there exists the risk that they will not be able to link the partnership to other key institutions in the local setting. Important stakeholders may be bypassed. Southern countries are particularly vulnerable to this. Another issue is that in some cases partners may be locked in collaboration that reinforces their respective national system's weaknesses. This can lead to one system perceiving the other to be free-riding on its resources. Significant tension in the overall bilateral relationship can result. Finally, issues may arise when national institutions attempt to align with foreign counterparts in order to promote collaboration. This may mean their having to adopt common institutional forms and practices that may, however, disrupt the functions they perform for their local system.
7.4 Modeling north-south collaboration in health biotechnology

The third objective of this research aimed to advance a conceptual model by which to better understand north-south S&T collaboration. As I discussed in chapter 2, I have relied on the innovation systems framework as a conceptual framework to guide this research. To recap, a system of innovation is comprised of a network of institutions that influences economic agents’ behaviour and shapes innovation capacity building resulting from science and experience based learning. Innovation results from the dynamic interactions of organizations and institutions including firms, universities, public research institutions, financing mechanisms, standard setting bodies, knowledge transfer practices, and industry associations, among others (Lundvall, 1992; Mytelka, 2000; Nelson, 1993). Some policy analysts have advocated that in order for collaboration to lead to innovation it needs to be perceived and promoted within an innovation systems framework (Chataway et al., 2005; Velho, 2002). I want to take the systems of innovation concept a step further and model international collaboration as interactions among the different innovation systems in the countries participating in the collaboration. This is illustrated in figure 10.
Figure 10. Conceptual framework to analyze collaboration as interaction of two innovation systems

(i) Misaligned systems

(ii) Systems in alignment
In figure 10, the circle at the interface of Innovation Systems A and B represents collaboration. Collaboration here can involve research partnerships, entrepreneurial alliances, or cross-border university-industry joint initiatives. Figure 10 has two sections; (i) represents instances where collaboration exists but has not resulted in innovation, and (ii) indicates situations where collaboration has resulted in innovation.

Innovation systems A and B represent two countries’ national innovation systems in figure 10. National systems of innovation differ from each other in terms of the institutions they are composed of as well as the patterns and density of linkages between their institutions. Each of the segments in Innovation Systems A and B represent the various institutions that comprise them. The institutions of systems of innovation are diverse. However, for simplicity’s sake, the complexity is not indicated in any detail in figure 10. Circular arrows at the centre of Innovation Systems A and B represent multidirectional linkages between institutions comprising the systems. Performance of national innovation systems depends upon not only the elements composing the system, but also the relations between them.

Institutions in both Innovation Systems A and B play a role to support collaboration such that it leads to innovation. Based on the empirical data in my study, I propose that those institutions involved in providing funding, those involved in knowledge transfer, and those that determine standards and regulate
product development activities have particularly strong impacts on the innovation potentials of the collaboration. Although my research highlighted these three key institutions, other institutions may be important for collaboration as well.

Institutions are considered to facilitate the dynamics of innovation (Edquist & Johnson, 1997). The role of the specific institutions indicated in figure 10 includes providing their country’s firms and researchers involved in international cooperation with incentives to pursue partnership in the first place (financing), supporting management of conflict in their joint activities (knowledge transfer), and reducing risks in the ventures they undertake (regulation).

For collaboration result in innovation, relevant institutions in the partners’ innovation systems have to be aligned to the collaboration initiative. The institutions from the innovation systems have to be connected to and provide the actors on their side involved in the collaboration with support. In figure 10 (i), these institutions in Innovation Systems A and B are not aligned to the collaboration initiative at the centre. Some institutions are not present at all; for example, the institution related to knowledge transfer in international partnerships is not present in Innovation System A in figure 10 (i).

In figure 10 (ii), institutions involved in financing, knowledge transfer, and regulation overlap with collaboration initiative from both Innovation Systems A and B. Here, financing agencies offer their local actors incentives in pursuing
collaboration with a foreign, unfamiliar partner. Knowledge transfer agencies help local researchers and firms by mediating conflict that may arise in negotiations. Regulators are able to advise about requirements necessary to bring potential products being jointly developed to market. This is unlike the situation in figure 10 (i). There the collaboration initiative is not on the radar of local institutions in a nation’s system of innovation; it is simply not acknowledged by the institutions. As a result, the system is unable to guide the collaboration such that it can result in innovative products and services. There is also the risk that a nation’s firms and researchers will miss out on their share of benefits resulting from partnerships.

For international collaboration to result in outcomes that address a country’s priorities, local institutions involved in supporting collaboration initiatives should be closely linked to each other. In figure 10 (i), institutions related to financing, knowledge transfer and regulation do not have frequent, intensive interactions or knowledge flows between them. This is not the case in figure 10 (ii); here institutions related to financing, knowledge transfer and regulation are closely linked to each other within their respective Innovation Systems A and B. If local institutions that assist in promoting collaboration have dialogue with each other, they can implement an integrated vision of how partnerships can fit with national priorities. It is important to link international collaboration to local priorities; otherwise, the outcomes of partnership to society are not maximized. Also, broad consensus is required among the stakeholders on how to encourage
international collaboration such that the goals of the domestic system are met and resources allocated towards it are not wasted.

In a situation where a country's funding, knowledge transfer and regulatory institutions indeed conversing with each other, the following dynamics and processes are possible. Joint projects that focus on addressing local health problems receive priority for financial support. Technology transfer offices have constant interface with domestic funding agencies and assist in licensing any technologies developed to local firms. Regulatory agencies maintain linkages to local funding agencies and technology transfer offices, are able to keep abreast of budding technologies from early on in their development through frequent contacts with relevant organizations and prepare themselves (potentially by upgrading their capabilities) to evaluate new-to-the-world technologies. This is the type of dynamic that is occurring in figure 10 (ii) for both Innovation Systems A and B. Having internal dialogue can maximize benefits of collaboration for the local innovation system. However, in order for institutions of the innovation system to be aligned to each other and to work together in priority setting with regards to international collaboration, they have to be aligned with each other in terms of their mandate and resources. Unless relevant domestic agencies have sufficient flexibility to operate in the international realm and are equipped with an adequate resource base to pursue such activities, they will not be able to engage in a balanced dialogue with each other about international collaboration.
For collaboration to lead to joint innovation, not only must the partnership be supported by a key set of local institutions in both partners’ countries, it is also important that these institutional actors are attuned to their foreign counterparts. There is need for cross talk between institutions from both partners’ national systems of innovation for joint innovation to take place. However, for institutions in two innovation systems to be able to work together to support collaboration, there needs to be alignment between them in critical aspects. Gray arcs indicate cross-border ties between counterpart institutions of Innovation Systems A and B that are in alignment in figure 10 (ii). In figure 10 (i), counterpart institutions in Innovation Systems A and B are not synchronized; this is depicted in spatial terms and there are no gray arcs connecting coordinated cross-border institutions. Misalignments in the institutions’ expectations regarding collaboration, cultures surrounding commercialization of research results, and processes to evaluate novel technologies are some factors that can constrain collaboration.

The different countries’ expectations of international collaboration can prevent partnerships from achieving innovation goals. One country may not prioritize collaboration to the same degree as the other because it may not expect to reap as much gain from collaboration. As a result of this belief, its funding agencies may not show much enthusiasm for allocating co-funding towards programs to encourage S&T collaboration or mobility of technical personnel. Its collaborating country may be more enthusiastic in supporting international collaboration but it
will need to see an equally interested response to its proposals from the
countries it collaborates with in order to invest substantial resources in the
collaboration. The misalignment of expectation thus hampers the collaboration.

Lack of alignment in culture regarding knowledge transfer and commercialization
can also impede collaboration from leading to innovation. Technology transfer
offices in one partner’s country may be proactive in marketing technologies
arising from research and finding potential industrial partners for their
researchers. However, counterparts in the other partner’s country may be
inexperienced. Technology transfer professionals from two national systems of
innovation may have different work cultures and priorities, and it can be difficult
for them to link efforts when managing collaboration.

Finally, misalignment in operating procedures between the participating
countries’ regulatory authorities can hinder collaboration. Guidelines of countries’
regulatory authorities stem from complex factors, including diverse evolutionary
paths of the agencies and national priorities. Lack of synchrony between the
counterpart regulators of collaborators’ countries can prevent their exchanging
information regarding inspections and product assessments. Lack of cross
border dialogue between counterpart regulators can lead to partnering firms
having to at the very least deal with non-congruent bureaucracies and at the very
worst repeat expensive proof of principle tests. There is no question that strong
regulation is paramount to ensure the safety and efficacy of products. However,
regulatory hurdles resulting from misalignments between two national systems of innovation can increase the financial burden on collaborators and lengthen the time for innovative products to reach populations that need them.

What the model described in this section shows is that collaboration is not just between individual researchers or firms. Rather, for joint innovation to result from international collaboration, the partnership must be aligned in critical aspects and involve interactions among larger sets of institutions locally and internationally. For collaboration to result in joint innovation, several types of interactions are critical. First, key institutions in both partners’ national innovation systems have to acknowledge the collaboration; they have to recognize the phenomenon has the potential to be valuable to the system. Secondly, internal dialogue within institutions of the innovation systems and their coordination is important for priority setting with regards to collaboration. Finally, external dialogue or cross talk between institutions across collaborators’ innovation systems provides cross border support to international collaboration. Alignment between institutions across national innovation systems can enable international collaboration carry on smoothly. The benefit of a model that views collaboration as interaction between two systems of innovation is that it draws attention to the importance of systemic alignments, and how misalignment in key areas can impede collaboration and its potential to result in innovation. Thus, policy-making to promote collaboration should entail identifying systemic misalignments and recalibrating the system to overcome them.
7.5 Policy implications

The final objective of this dissertation was to identify the policy implications of this research for Canada's collaboration with the emerging economies. To do so, I relied on interviewee suggestions, comparison with what other developed countries are doing in promoting collaboration with emerging economies, and analysis of my data through the lens of interactions of innovation systems. The policy areas discussed below are informed by the empirical data collected in this study as well as the processes I described in the preceding model. About 60 Canadian policymakers provided their feedback regarding the policy areas at a workshop in Ottawa held in June 2010.

Increase resources for research collaboration

There was a consensus among scientists interviewed in Canada, Brazil and India that the lack of dedicated funding for Canada-Brazil and Canada-India research projects was a significant challenge. They generally did not have any dedicated funding to support their research collaboration, but instead used portions of their own research grants.

As was discussed in chapter 6, although emerging economies are interested in investing funds to foster collaborative research programs with Canada, Canadian funding agencies have been hesitant to allocate co-funding to these initiatives.
One reason for this may be the decline in their research budgets in recent years. The CIHR is the main Canadian funding agency that can foster research collaboration between Canadian and emerging economies scientists in the health field, but the level of funding it has provided towards fostering such partnership with the emerging economies thus far is small. The ISTPP initiative, although it supports research collaboration in high technology fields, stresses innovation and requires the involvement of firms in collaborative projects. Collaborating scientists were keen about the possibility of getting funding from this program, but felt that the requirement for industrial involvement limited opportunities for research collaboration. Not all research collaboration is of a sufficiently applied nature to be of industrial interest, so scientists engaging in early stage research were disappointed that there seems to be limited public policy interest in supporting Canada-emerging economies collaboration on more basic research topics. It is noteworthy that firms interviewed in this study did not stress a need for further government research funding to support collaboration, but rather wanted support to initiate first contact with potential collaborators.

In contrast to the efforts being undertaken in Canada, some other developed countries are investing significant resources to promote collaboration with the emerging economies in S&T fields. For example, Australia established the Australia-India Strategic Research Fund in 2009, and has committed to providing $ 50 million over five years to stimulate collaboration with India, with specific focus on biotechnology-related projects. The Australian program allocates far
greater funding to promote S&T partnership with India than the Canadian ISTPP initiative does (as indicated in chapter 6, $6.75 million over five years). Also, unlike the ISTPP initiative, the Australian program makes it possible for research teams to include private sector partners, but does not require them to do so (Australian government website).

Interview evidence from India indicates that there was misalignment in expectations of the funding levels arranged through the ISTPP initiative. The Indian side appears to have been willing to provide co-funding to fund collaboration with Canada at a level comparable to its other northern partners. Some interviewees in India expressed surprise at the low level of funding offered by the Canadian government. Considering that India has allocated considerable resources to collaboration with Australia, it is credible that they were aiming for a more ambitious funding program to support Canada-India collaboration. India’s science budget has increased significantly in the last few years (Jayaraman, 2009). India thus appears to be ready and willing to allocate funds towards joint scientific research with Canada, but Canada seems to be tentative in matching resources. This reflects a systemic misalignment in terms of expectations between the two innovation systems, likely to result in hampered collaboration and missed opportunities.

It is important that Canada increases funding for research collaboration with the emerging economies and provides sustained support for joint projects. Such a
move is an acknowledgement by Canada that it regards building research ties with the emerging economies to be of value and lives up to the expectations of Indian and Brazilian funders. Without further investment from Canada, there is a risk that it will be left out of emerging knowledge networks involving southern countries. Considering the constraints of research funding in Canada, it is important to consider alternative funding solutions rather than relying only on federal funding resources to encourage Canada-emerging economies research collaboration. One option to consider is federal-provincial funding partnerships. For instance, provincial governments can step forward to co-fund projects originating from their institutions that have been successful in federal competitions. The government of British Columbia has worked with ISTPCanada to support British Columbia-India S&T projects. Greater coordination between Canadian funding agencies at the provincial and federal levels can help to better support Canadian academics in their north-south collaboration initiatives.

**Mobility of scientific personnel**

Lack of opportunities for mobility of scientific personnel was found to be a challenge impeding Canada-emerging economies research collaboration. Brief research visits by key collaborators, in which they can establish their collaboration and build trust, coordinate research efforts and jointly analyze their results are useful for scientists. Some of these activities can be done over e-mail and telephone, but face-to-face meetings are of paramount importance. As seen
in the Canada-Brazil and Canada-India collaboration in health biotechnology

In the Canada-Brazil and Canada-India collaboration in health biotechnology case studies, Canada lacks programs to support such short visits. For instance, the aim of the Government of Canada Post-Doctoral Research Fellowships Program is to promote exchange, network building and collaboration with countries including the UK, France, Switzerland and Japan. Brazil is the only emerging economy included among the program’s target nations. In 2010, seven awards were offered to Brazilian researchers to carry out post-doctoral studies in Canada under this program. Japan, in contrast, is emphasizing attracting post-doctoral fellows from emerging economies. In 2008, over a hundred post-doctoral fellows from China and India each were supported by the Japanese government to conduct research in Japan (Japan Society for the Promotion of Science, 2008). It appears that Canada’s mobility programs are eclipsed by the initiatives of some other developed nations.

When scientists were asked for suggestions on how to strengthen Canada-emerging economies S&T collaboration, they most frequently raised the hope for increased opportunities for student exchanges. There appeared to be a high demand for sending graduate students from the emerging economies to Canada to gain access to particular research infrastructure or for training in specific technologies. The need to send Canadian graduate students to emerging economies was also mentioned. In general, student exchanges were considered important not just in order to complete specific research projects, but for long-term collaboration between Canada and the emerging economies. When
students are exposed to and learn to operate in different cultural and scientific environments, they become more open to collaboration with emerging economies. In many instances, interviewees described how graduate students who had opportunities for student exchanges continued to collaborate with the international partners on their own. Exchange programs promote greater familiarity and trust between research communities, and these form the core of successful collaboration.

There is a risk of 'brain drain' from developing countries through student exchanges, if students decide to stay in Canada instead of returning to their home countries after their training. Cases where this happened were observed, particularly in Canadian collaborations with Brazilian scientists. Interestingly, many emerging economies researchers did not express concern about brain drain, but described benefits to their home countries of having their former students working in Canada. For instance, they argued that although students choose to remain, that they continue to contribute to research in their home countries. However, policymakers in Brazil did not share the same views. They are keen on their research personnel returning back to their home country. To counteract against effects of brain drain, emerging economies policymakers are interested in programs that support two-way exchanges of personnel.

One way Canada can strengthen mobility is by supporting initiatives to support interactions of scientists it has attracted from emerging economies with their
countries of origin. Previous research has shown that diaspora scientists are highly motivated to give back to their countries of origin, but need formal programs to support their interactions (Seguin et al., 2006). There is willingness by Canadians, particularly within the diaspora community, to forge closer ties with emerging economies in the form of short visits and provision of training. Such programs can enable Canada to leverage its highly qualified diaspora population to foster greater ties with the emerging economies. Plans to engage diaspora communities to promote collaboration with their countries of origin may be linked to programs aimed to facilitate the establishment of professionals immigrating to Canada in their respective fields, which is a national priority. Citizenship and Immigration Canada has jointly implemented pilot programs with Human Resources and Skills Development Canada to integrate newcomers into the Canadian labour market (Government of Canada website). These institutions can form further links to DFAIT, and connect their programs with DFAIT’s S&T mobility initiatives with the emerging economies. Aligning key Canadian institutions, concerns and priorities can increase the sustainability of programs aimed at encouraging collaboration with the emerging economies in S&T.

Policy coordination

The results of this study indicate that lack of coordination among various Canadian agencies, departments and institutions working to support S&T collaboration with the emerging economies can impede partnership. Canada’s
science system involves both federal ministries and provincial governments
directing scientific research and higher education. The federal government
administers funds for R&D, and the provincial governments govern higher
education. Canadian universities have considerable autonomy over content and
conduct of research (Williams, 2007). A bottom-up approach has nurtured
regional S&T strengths and promoted local specializations in Canada.

However, Canada’s federal, provincial and university level institutions appear to
be implementing autonomous initiatives in terms of cooperation with emerging
economies. This was described in the Canada-India case study in this
dissertation. Lack of coordination can be a challenge for emerging economies
wanting to collaborate with Canada, and it has been difficult for policy makers in
emerging economies to have to deal with multiple institutions in Canada that
have the same agenda. This puts additional demands on administrators in
emerging economies; they have to receive numerous delegations from Canadian
universities, funding agencies, provinces and ministries, all knocking on the same
door with similar, overlapping interests. The Brazilian policymakers stressed, for
example, that it was not clear whom to approach in Canada. This can be a
frustrating experience.

Lack of coordination can also prevent optimal use of resources. Without policy
coordination among domestic institutions, financial resources are not pooled;
priority sectors and priority countries are not established; efforts are duplicated
and no learning takes place across programs; and finally, it is difficult to achieve
critical mass in terms of resources and administrative support on any one
initiative.

The innovation system in Canada is disjointed when it comes to promoting
collaboration with the emerging economies. The lack of internal dialogue and
integration among Canadian institutions regarding their vision and
implementation of programs towards promoting partnership hinders effective
interaction with institutions on the emerging economies side that are working to
manage collaboration. In contrast, Germany’s DAAD (German Academic
Exchange Service/ 'Deutscher Akademischer Austausch Dienst') works at the
interface of various interrelated policy fields: national higher education policy,
cultural policy and development policy. The DAAD has the formal mandate and
budget to mediate among various federal ministries, between the state and
higher educational institutions, and between academic community and
politicians. It is in a position to hold consultations with diverse German
stakeholders and to determine internal priorities Germany has with respect to
collaboration with emerging economies before approaching emerging economies
to negotiate bilateral frameworks for S&T collaboration (DAAD, 2008). Numerous
interviewees in Brazil and in India commented on the success of Germany’s
DAAD in strengthening S&T collaboration between their countries. The example
of the DAAD suggests that consultation between diverse stakeholders of a
country’s systems of innovation and integration of their activities can bring
greater coherence to their approach to pursuing international collaboration while keeping national priorities in clear view. It can also make it easier for other countries to engage with its national innovation system.

There is no comparable agency in Canada that has the mandate or resources to operate at the crossroads of various Canadian S&T policy domains as the DAAD is able to do. Canadian public policy can consider potential focal organizations to provide leadership in centralizing Canada’s efforts in this regard. The AUCC, for example, has had experience working with CIDA and Canadian universities in implementing capacity building projects in developing countries. There is the potential for such an institution to promote greater internal dialogue and alignment between various Canadian science-based agencies at the federal and provincial levels about applying a coherent approach to collaboration with the emerging economies. Canadian policymakers have to consider the benefits and challenges of centralized efforts and which institutions can take on such a role.

**Firm internationalization**

Firm executives interviewed for this study stressed that lack of information was the main barrier to collaboration between Canada and the emerging economies. Canadian health biotechnology firms are primarily small in size. They felt they did not know enough about firms in emerging economies and that it is challenging for them to identify suitable partners thousands of miles away. This message was
echoed by firms in emerging economies as well, who said they knew more about biotechnology firms in the US and the UK than firms in Canada.

Canadian firms find that language barriers, cultural and bureaucratic differences, and limited transparency in emerging economies add a special layer of difficulties. Local partners are, therefore, critical. However, small Canadian firms do not have the resources to carry out the necessary due diligence to find local partners in emerging economies. These firms have to be particularly careful when picking a partner that is trustworthy due to intellectual property rights infringement fears; their small size means they have limited opportunities to make mistakes.

While financing opportunities for travel and networking are certainly important for Canadian firms, they also need advice on establishing collaborations. Trade commission offices generally provide such advice, but they may not be well suited to deal with the particular needs of high technology firms. Scholars have also pointed out that Canadian embassies and consulates’ abilities to deal with S&T at this time are limited (Dufour, 2002; Copeland, 2009). Thus, there is a demand for Canada to provide more targeted support for firms in science-intensive fields.

To take first steps in establishing collaboration, there is need for ‘matchmaking’ services between Canadian and emerging economies’ firms. With matchmaking
programs, firms rely on Canadian as well as local contacts to screen and pre-qualify potential partners. Other developed nations have such initiatives in place. The Netherlands’ Package4Growth program, for example, is targeted towards helping Dutch high technology firms to specifically enter the emerging economies. The program offers Dutch firms on-the-ground support when navigating emerging economies’ markets. Package4Growth relies on local emerging economies contacts to evaluate potential partners before linking them to Dutch firms. Here there is considerable alignment and coordination between the interests of northern and southern institutional actors in enabling joint ventures between their countries’ firms to be formed.

Apart from matchmaking services, there is demand for business mentoring early on in Canada-emerging economies firm alliances. Some developed countries have established private sector initiatives to provide their firms support establishing linkages in emerging economies. For instance, ChinaBIO LLC, formed by US business consultants, provides advice to life sciences entrepreneurs in the US and China interested in targeting each other’s markets (ChinaBIO LLC website). Public-private partnerships can be useful in providing similar services. One model suggested is a partnership between governments and venture capitalists in the participating countries. It would involve establishing a fund with joint financing from venture capital groups in each country, along with contributions from the governments of Canada and that of the emerging economy. Canadian and emerging economies companies would be given the
opportunity to submit a proposal involving their collaborative efforts. Venture capital groups in the two countries would evaluate the proposals. Proposals would have to be accepted by the venture capital firms in both participating countries in order to be successful. Venture capitalists would work together to provide business mentoring to the firms. Including venture capital from both participating countries would ensure that there is shared knowledge flow about local conditions in each country and that partnering firms have access to funding support and guidance.

For an initiative such as this to work will require significant cross border alignment in terms of expectations, work cultures and operating procedures between public and private institutional actors in Canada and its emerging economy partner. Successful collaboration with Canada can signal the appeal of collaboration with Canada to other firms in the emerging economies.

**Regulatory cooperation**

As discussed above, health innovation is becoming increasingly global, with different phases of the innovation process crossing national borders. Firms are engaged in international collaboration in their activities to develop novel health technologies, and can take advantage of the diverse strengths of the innovation systems of different countries. Preclinical research may, for example, take place in two or more countries, and the different phases of clinical trials for a single
drug candidate are not confined within national borders. For Canada’s firms, it can be an opportunity to be able to collaborate with emerging economies and benefit from the strengths these economies can offer to the innovation process. Still, globalizing Canada’s innovation is not without challenges, and it can add to the regulatory burden for health biotechnology firms to conduct innovation that crosses national borders, especially when technological and administrative requirements of regulatory systems differ widely among nations. It is possible that with greater dialogue, recognition and alignment between regulatory agencies of Canada and the emerging economies may enable greater understanding between them and further cultivate the joint innovation process.

The role of health regulation has been to ensure that marketed products are safe and effective. However, in the new millennium, it has become increasingly recognized that regulatory systems play a significant role in the innovation process (Tait et al., 2007). The complex relationships the regulatory systems have with firms involved in developing new health products have significant influences on how fast and effectively firms can develop their products and services.

In order to foster new-to-the-world innovation that takes advantage of potential global strengths, adjustments have to be made in order to streamline the regulatory process when international partners work together. There is need for greater regulatory understanding between nations. This is the premise that has
led to the harmonization of drug regulation laws in the EU under the umbrella of the European Medicines Evaluation Agency (EMEA). Greater regulatory coordination improves competitiveness of European firms by promoting greater collaboration in R&D, reducing their application burden, expanding their market size and enabling speedier approval times. A cross-border yet streamlined system can enable good quality evaluation and time efficient drug approval, which is important for patients in the jurisdictions served.

The EU example suggests that several national regulatory agencies can work together to have considerable leverage in promoting international firm collaboration and joint innovation. Canadian regulators should consider the role they can play in fostering international collaboration and innovation as well. With increasing collaboration in drug development between Canada and the emerging economies, there is demand for further collaboration in drug development between their regulatory systems. Cooperation with regulatory authorities in developing countries in some areas such as vaccine trials has improved the evaluative process of health products (de Andrade Nishioka, 2008). For example, Health Canada works with the Chinese State Food and Drug Administration in the area of traditional medicines (Health Canada website). Greater alignment between Canadian and the emerging economies’ regulatory frameworks could make it more conducive for collaborating firms to conduct R&D activities across borders.
7.6 Some limitations of this study and areas of future research

Even though this study represents a thorough examination of Canada’s collaboration with emerging economies, the research is not without its limitations. First, I studied research and entrepreneurial collaborative projects that exhibited at least some success. This is a result of the methodology applied to identify collaborative initiatives to examine in this study. I selected research collaboration projects that had led to at least one joint publication. I chose entrepreneurial collaboration initiatives where partners had achieved some outcome and were willing to speak about their experiences. However, not all research collaborations produce publications, and not all entrepreneurial collaborations are able to attain desired milestones. There may be important dynamics and processes embedded in partnerships that did not achieve impact whose study can further inform what constitutes successful collaboration. It would be of interest to study projects of this sort and examine how they differ from the projects examined in this dissertation.

Secondly, further research could look at how credit is allocated in north-south S&T partnerships. Even though this study shows relative equality between Canadian and emerging economies partners in designing, conducting and analyzing data in joint projects, it is possible that there are instances where credit
is allocated disproportionately. It is difficult to evaluate this through the interview strategy alone, as collaborators may feel uncomfortable talking about such issues. Application of ethnography research strategies whereby collaborators are followed by the research team for longer periods of time may yield greater insight into this.

An important finding of this study is that greater alignment between institutions involved in supporting S&T in northern and southern countries is required to foster collaboration. I focused my analysis in this dissertation on research funding agencies in Canada and the emerging economies, on institutions that play a role in assisting firms to internationalize and on drug regulatory authorities. These are institutions and topic areas that were stressed by interviewees in my field work. However, the study shows that collaboration between Canada and the emerging economies is relatively young, but as it progresses partnerships may experience different needs that have to be met by other types of institutions. One area that is likely to take on greater emphasis as joint projects yield more outcomes is that of intellectual property rights negotiation between partners and the role of technology transfer units and knowledge transfer practices in Canada and the emerging economies. Future research may involve examining if Canadian and emerging economies are taking steps to increase cooperation with each other in this area.
Finally, future research can examine north-south S&T collaboration involving other technological sectors (information and communications technologies, green technologies, etc) as well as other developed-developing country pairs. It would be interesting to explore the dynamics and institutions at play in such international S&T relationships, and to what extent these are similar or dissimilar to the processes uncovered by the research in my dissertation. Comparative studies would enable deeper perspective as to how Canada is a unique northern partner in S&T fields for southern countries.

**7.7 Conclusions**

In this dissertation, I examined Canada-emerging economies collaboration in health biotechnology. I studied both research collaboration and entrepreneurial collaboration. I also considered how the institutional environment in Canada and the emerging economies influences collaboration.

As the economic standing of Brazil and India grows, these countries are increasing their support of domestic S&T. This has led to the development of local strengths and specializations in the health biotechnology field as well. The Canadian researchers and firms I examined are interested in gaining from this expertise. They consider it to be complementary to their own abilities, and important to further joint projects towards their successful completion. Although they realize that that their peer communities at home may potentially harbour
biases against science conducted in the emerging economies, their actual experiences with collaboration have enabled them to recognize that such foreign science is hardly alien. In several cases, I found Canadian scientists and entrepreneurs continuing to work with emerging economies partners, and assisting them to showcase their research even though they were concerned in what light such efforts would be seen by peers at home. They did so because they believed the joint research created was unique, of good quality and contributed towards furthering the scientific knowledge base. In many instances, the joint research helped further innovation goals as well.

My research shows that Canada-emerging economies collaboration in the field of health biotechnology can lead to mutually beneficially outcomes for the research and entrepreneurial partners involved. However, overall, Canadian scientists' and firms' ties with counterparts in Brazil and India, however, are modest at this time. The Canadian government is not investing enough resources towards supporting partnerships with the emerging economies in such high technology fields, particularly in terms of basic research. Without more resources, it is unlikely that there will be radical increases in Canada's levels of collaboration with the emerging economies. Collaboration initiatives also do not receive support to mitigate potential risks of partnerships and it is uncertain how well Canadian public policy is able to gear partnerships to meet national priorities. The various Canadian institutions at the federal and provincial level that have a role in addressing these issues do not have strong linkages with each other and are not
working with each other in a cohesive, coherent way to encourage the direct interaction their scientists and entrepreneurs with counterparts in the emerging economies.

What my analysis suggests is that for collaboration to lead to joint innovation, not only must it be supported by a larger set of institutions in both partners’ countries, but it is important that these institutional actors are well attuned to their foreign counterparts. If these relationships are not aligned, it is unlikely they will be able to provide collaboration initiatives with appropriate guidance and that collaboration will be sustainable and innovative. Due to the critical role synchrony of innovation systems plays in partnerships leading to impacts and being sustainable, collaboration can be viewed as being the result of the interactions of innovation systems. Thinking about collaboration as interactions of innovation systems brings into the analysis diverse institutions and policy domains that may not have been considered before. It highlights the importance of a multi-pronged policy approach in encouraging north-south S&T collaboration.
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Appendix A: Survey questionnaire

UNIVERSITY OF TORONTO STUDY - NORTH-SOUTH COLLABORATION IN HEALTH BIOTECHNOLOGY

Dear Sir/Madame,

Cultivating strategic alliances has become essential for firms to prosper in today’s world. The Canadian Program on Genomics and Global Health (CPGGH) at the University of Toronto wants to contribute towards cultivating Canadian biotechnology alliances with emerging economies by conducting a study on ‘Canada’s Health Biotechnology Collaborations with Developing Countries.’ The aim of the research is to examine how health biotechnology collaborations with developing countries can be advantageous to both parties in terms of economic benefits and strengthening innovation potentials as well as important in contributing to global health objectives. This research is supported by the Canadian Institutes of Health Research (CIHR).

The first phase of the project involves mapping Canadian collaborations with developing countries. We hope that you will kindly help us by completing this brief survey. The survey will take no more than **5 minutes** of your time and only requires that you respond to a few questions about your firm’s collaborations with developing countries. If you do not collaborate with developing countries you will only need to answer a total of 2 questions for this survey. If you collaborate with developing countries the total number of questions we ask you to answer is 10.

‘Canada’s Health Biotechnology Collaborations with Developing Countries’ is a follow up project to a multi-country study we conducted on ‘Health Biotechnology Innovation in Developing Countries’. It pointed to the importance of collaboration for innovation in biotechnology and its results were published as a special supplement of *Nature Biotechnology*. For more information on the study see [http://www.utoronto.ca/jcb/home/news_nature.htm](http://www.utoronto.ca/jcb/home/news_nature.htm)

Please note that your responses will be kept confidential and that any communications discussing the results from this survey will be presented in an aggregate format and will not disclose the identity of your firm without your prior consent.

For the survey, we are following the World Bank’s definition of developing countries and include, for example, both emerging economies such as Brazil, China and India and low income countries such as Bangladesh, Bolivia and Malawi. Please use the link below to access a list of countries that fall into the developing countries category.

[http://www.utoronto.ca/jcb/genomics/documents/List_Developing_nations.htm](http://www.utoronto.ca/jcb/genomics/documents/List_Developing_nations.htm)

We follow a broad definition of collaboration and would include any work towards producing knowledge/products and services in health biotechnology that are undertaken jointly by firms/organizations in different developing countries.

We greatly look forward to your participation and very much appreciate your time and expert input into this study. We hope this study will contribute to strengthening entrepreneurial linkages between Canada and emerging economies. If you are interested, we would be happy to share with you final results of the survey once the study is complete.
I have read the above and consent to participate in this survey:

YES ______ NO ______

Name of firm: __________________________________

1. Does your firm collaborate or work together in any way with firms or organizations in other developing countries? Please mark appropriate option with an ‘X’.

YES ______ NO ______

If ‘NO’ please go to Question 10

2. If ‘YES’, please list the collaboration initiative by presenting the name and location of the partner firm/organization (e.g. ABC Inc., China).
   If you collaborate with more than five firms/organizations, please feel free to expand the list.

1. 
2. 
3. 
4. 
5. 

3. What activities do each of the collaborations entail?
   Please follow the order of collaboration initiative listed above in Question 2 and mark the appropriate activity with an ‘X’. Choose as many activities as are relevant to describe the collaboration.

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<th>Laboratory Services</th>
<th>Clinical Trials</th>
<th>Manufacturing</th>
<th>Providing Supplies</th>
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<th>Training</th>
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Please expand if needed:
4. What are the reasons for the collaborations?
Please follow the order of collaboration initiative listed above in Question 2 and mark the appropriate activity with an 'X'. Choose as many reasons as are relevant to describe the collaboration.

<table>
<thead>
<tr>
<th>Access to market</th>
<th>Gain knowledge</th>
<th>Access to technologies/equipment</th>
<th>Access to patients</th>
<th>Access to financing</th>
<th>Provide markets</th>
<th>Provide knowledge</th>
<th>Provide technologies/equipment</th>
<th>Provide patient access</th>
<th>Provide financing</th>
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Please expand if needed:

5. What types of technologies does each of the collaborations involve?
Please follow the order of collaboration initiative listed above in Question 2 and mark with an 'X' all applicable technologies.

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<tr>
<th>Vaccines</th>
<th>Biopharmaceutical</th>
<th>Diagnostics</th>
<th>Pharmaceuticals</th>
<th>Drug Delivery Systems</th>
<th>Bioinformatics</th>
<th>Other (please specify)</th>
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6. What type of partner organization(s) is your firm cooperating with?
Please follow the order of collaboration initiative listed above in Question 2 and mark with an 'X' all applicable responses.

<table>
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<tr>
<th>Firm</th>
<th>Research Institute</th>
<th>University</th>
<th>Hospital</th>
<th>Government</th>
<th>Other (please specify)</th>
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Please expand if needed:
7. What types of formal arrangements have your firm established with your collaborator(s)?
   Please follow the order of collaboration initiative listed above in Question 2 and mark with an ‘X’ all applicable responses.

<table>
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<tr>
<th>Joint Venture</th>
<th>Licensing Agreement</th>
<th>Strategic Alliance</th>
<th>Subsidiary</th>
<th>Memorandum of Understanding</th>
<th>Other (please specify)</th>
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8. What types of outputs have each of the collaborations produced?
   Please follow the order of collaboration initiative listed above in Question 2 and mark with an ‘X’ all applicable responses.

<table>
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<tr>
<th>Joint Product on Market</th>
<th>Joint Product in Pipeline</th>
<th>Joint Patent</th>
<th>Joint Publication</th>
<th>Other (please specify)</th>
<th>None</th>
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Please expand if needed:

9. Who initiated the collaboration?
   Please follow the order of collaboration initiative listed above in Question 2 and mark with an ‘X’ all applicable entities.

<table>
<thead>
<tr>
<th>Your Firm</th>
<th>Partners in developing Countries</th>
<th>Canadian Government Agencies</th>
<th>Developing Country Government Agencies</th>
<th>International Organizations</th>
<th>Expatriates</th>
<th>Other (please specify)</th>
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Please expand if needed:
10. Does your firm collaborate with firms or organizations in industrialised/high income countries?

Please use the link below to access a list of countries that fall into this category:

http://www.utoronto.ca/jcb/genomics/documents/List_Industrialized_HighIncome_nations.htm

YES ______ NO ______

If YES

If ‘YES’, please list the collaboration initiative by presenting the name and location of the partner firm/organization (e.g. DEF Inc., France).

1. 
2. 
3. 
4. 
5. 

Thank you very much for your help! We highly appreciate your time and expert input into this study. Please let us know if you are interested in seeing the final results of the survey once the study is complete.

YES ______ NO ______

Please feel free to provide comments or clarifications on any aspects of the survey

_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

Please return the completed survey as soon as possible.

If you have any questions or concerns about the survey please contact:

Monali Ray
Graduate Student, Institute of Medical Science
University of Toronto
Email: monali.ray@utoronto.ca
Appendix B: Interview guides

INTERVIEW GUIDE FOR RESEARCHERS

Name of Interviewee:
Date:

Background

1. Can you give me a brief overview of your group?
   What are your institute’s main focus/capabilities?
   Please include a little about your background and previous experiences in the health biotech field.

2. Approximately what proportion of your research projects do you carry out in international research collaboration?

3. Who are the main partners you collaborate with?
   From which countries?
   From what types of organizations do they come? (public research institutions, hospitals etc),

Collaboration

4. What are the main reasons for you to take part in the collaboration on this paper?
   Would you be able to complete the research project without this collaboration
   Would your partner be able to complete the research project without this collaboration
   Do the same reasons apply for your other collaborations- with the different types of partners?

5. How would you describe your contributions to this international collaborative project?
   What did your colleagues contribute to the project?

6. How did you become interested in the research area of this collaborative project?
   Did you or your collaborators suggest it?
   What are your main sources of innovative ideas for the joint project?

7. How did you get to know your collaborators? (conferences, literature, etc)

8. Where did you get funding to carry out this project? (Please name the funding source)
   Do you and your partners apply for funding jointly or separately?
   Has funding been easily available and sufficient?

9. Is this collaboration arranged between institutions or between individuals?
   Is it formal or informal in nature?
10. Are there any graduate students or junior researchers in your group who are being trained through this particular project?

11. Do you consider this collaboration to be successful?
   What are your criteria for a successful collaboration?
   If successful, what contributed to the success of the collaboration?
   How successful was it compared to your other collaborations?

12. How many publications have resulted from this project/collaboration?
   In which journals?
   Is it fairly straightforward to decide who should be first author?

13. Have you encountered any problems with this collaboration?
   If yes, what were these problems and how did you address them?
   Are you satisfied with the outcome?
   How about your other collaborations, did you encounter problems with them?
   Was there any time in this collaboration that you felt it was too difficult?

14. Did you ever have to transfer material across to India and vice versa during this project?
   If so, how do you find the system for material transfer works?

15. Did you encounter any moral or ethical concerns in this collaboration?
   Did your collaborator in any way push for you to carry out the research in a way that you felt didn’t totally fit the norms and cultures in your country?
   Did you feel that your collaborator was in any way pushing for too much influence on the project, or to get more than a fair share of the project’s benefits?
   If yes, what were these concerns and how did you address them?
   Are you satisfied with the outcome?
   How about your other collaborations, did you encounter ethical concerns with them?

16. What do you feel that you learned from working on this project that you previously did not know?

**Output/impacts of the collaborations**

17. Are the findings of this collaborative research likely to have practical applications?
   If yes, what are these applications? (new products, clinical practices, etc)
   Do the findings have relevance for addressing local health needs?
   If so, how likely is it that they will have access to the products/services?
   Are the findings also relevant to health needs in countries such as the US or Canada?

18. How can the potential practical applications be realized?
Are you and your Indian partners working to take this project further?
What are the main activities that you are undertaking or planning?
If not, why are you not working to realize these practical applications?
Have you and your collaborators approached any organization or individual to take the project further? If so, whom?
From whom do you seek support to take the project further?

19. Has any IP/patent been generated from this collaborative project?
   If yes, what is the agreement on IP/patent sharing?

20. What are some factors that encouraged the project (policies, special programs, etc)?
   Did you take advantage of any special policies/programmes?
   Did being part of an international collaboration make it easier to have access to incentives?

21. What were the barriers the project faced?
   How did you address them?
   Was being part of an international collaboration useful in overcoming barriers?

Policies/plans

22. What are the key organizations in the health biotechnology sector that have influenced this project (funding agencies, regulatory bodies, universities, NGOs, user groups, private firms, international organizations, laws)
   What are the key organizations in Canada and [Brazil/India] that have influenced the project?
   How have they influenced the project?
   Do you consider the influences of/linkages with these organizations have been beneficial?
   What were some of the challenges in establishing and maintaining linkages with these organizations?

23. How do you think this collaboration could be strengthened to encourage innovation?
   Are there any wider institutions/factors that would help this happen?
   How can Canadian and [Brazilian/Indian] institutions prioritize areas of interest in which to direct collaborative research?

24. How do you think this collaboration could be strengthened to encourage global health?
   Are there any wider institutions/factors that would help this happen?
   How can Canadian and Brazilian/Indian institutions prioritize areas of interest in which to direct collaborative research?

25. What could the Canadian government do to promote effective collaboration with Brazil/India?
   How about the Brazilian/Indian government?
How about any international organization?

26. How do you view the prospects of collaborating with Canadian/Brazilian/Indian organizations in general?
   Both public and private?
   Do you plan to continue to collaborate with this team?
   Is there anything particular about India that makes them particularly attractive partner versus other countries for you?
   Do you think there has been a shift in prospects to collaborating with Indian researchers over time?

27. Does your institution place a larger emphasis on collaborations with industrialized nations rather than collaboration with emerging economies?
   If so, why?

28. Is there anything else you would like to discuss that you feel is relevant to this topic?
INTERVIEW GUIDE FOR FIRMS

Name of Interviewee:
Date:

Background

1. Can you give me a brief overview of your firm?
   What are your company’s main focus/capabilities?

2. Approximately what proportion of your firm’s activities do you carry out with other countries?

3. Who are the main partners that you collaborate with?
   From which countries?
   Are these mostly firms? Or are they other types of entities?

Collaboration

4. How was the alliance between your institute/organization and partner formed?
   Who initiated the collaboration?

5. What were the reasons for choosing to do this work in partnership with a firm in Canada/Brazil/India?
   Would your firm have been able to do the work without international collaboration?
   Would your partner have been able to do the work without international collaboration?
   Do the same types of reasons apply for your other collaborations?

6. How would you describe your main contributions to the project?
   What did your partners contribute to the project?
   When you were setting up the collaboration how did you evaluate the different partners’ potential contributions to the collaboration?

7. What are your main sources of innovative ideas for research and development in the collaboration project?

8. Do you consider this to be a successful collaboration?
   What are your criteria for a successful collaboration?
   If successful, what contributed to the success of the collaboration?
   How successful was it compared to your other collaborations?

9. Did you encounter any problems with the collaboration?
   If yes, what were these problems and how did you address them?
   Are you satisfied with the outcome?
How about your other collaborations, did you encounter problems with them?

10. Did any moral or ethical concerns influence the collaboration?
   If yes, what were these concerns and how did you address them?
   Are you satisfied with the outcome?

Project

11. What types of formal arrangements have you established with your partner?

12. What are the main outputs from this collaborative project?
   Does the project have practical applications? If yes, what are these Applications?
   How does it have relevance for addressing health challenges in developed countries?
   Does it have relevance for addressing local health needs in Brazil/India?

13. Where would you like to see this project go?
   Are you and your partners working to take this project further?
   What are the main activities that you are undertaking or planning?
   If not, why are you not working to realize further endpoints?
   Have you or your collaborators approached any individual/organization to take the project further? If so, who?

14. What are your firm’s manufacturing capabilities?
   What are your arrangements for bringing products through development/clinical trials?

15. What are your sources of funding for the collaborative project (government agency, angels, financial institutions, VCs, NGOs, diaspora, etc)?
   Did you and your partner apply for funding jointly or separately?
   Has funding been easily available and sufficient?

16. Has any IP/patent been generated from the collaborative project?
   If so, what is the agreement on IP/patent sharing?

17. Have you sought regulatory approval for a product resulting from this collaboration?
   If so, in which countries did you seek regulatory approval?
   From which regulatory bodies?
   Do you find that the regulatory systems in Canada and Brazil/India are harmonized?

18. What are the target markets for the product resulting from this collaboration?
   What is your pricing scheme?
   What is the agreement for splitting of revenues for the two collaborating
19. What were barriers the project faced?
   How did you address these issues?
   Was being part of an international collaboration useful in overcoming barriers?

20. What were some policies/special programs that encouraged the project?
   Did you take advantage of any special policies/programs?
   Did being part of an international collaboration make it easier to have access to incentives?

Policies/plans

21. What are the key organizations in the health biotechnology sector in Canada/Brazil/India that have influenced this particular project (government, public research institutions, universities, NGOs, user groups, funding agencies, private firms, international organizations, regulatory agencies, laws)?
   How have they influenced the project?
   Do you consider the influences/linkages with these actors to have been beneficial?
   What were some of the challenges in establishing and maintaining linkages with these organizations?

22. How do you think this collaboration could be strengthened to encourage innovation?
   Are there any wider institutions/factors that you feel could help this happen?

23. How do you think this collaboration could be strengthened to encourage global health?
   Are there any wider institutions/factors that you feel could help this happen?

24. What could the government of Canada do to promote effective collaboration with Brazil/India?
   How about the Brazilian/Indian government?
   How about any international organization?

25. How do you view the prospects of collaborating with Brazilian organizations in general?
   Do you plan to continue to collaborate with this team?
   Is there anything particular about Canada/Brazil/India that makes them a particularly attractive partner versus other countries for you?

26. How does your collaboration with firms/organizations in low and middle income countries compare to collaboration with high income countries in general terms?
27. Does your company place a larger emphasis on North-South collaboration, rather than collaboration with emerging economies?
   If so, why?
   How do they differ?

28. What measures do you think governments and international organizations could make to strengthen North-South collaboration in general?
   What do you think can be done to help firms initiate collaboration?
   What can be a way to match complementary entrepreneurial partners?
   Do you sense a lack of awareness of the capabilities of Canadian/Brazilian/Indian firms?

29. Do you see a role for VCs in Canada/Brazil/India in facilitating collaboration?

30. Is there anything else you would like to discuss that you feel is relevant to this topic?
INTERVIEW GUIDE FOR INNOVATION SYSTEMS ACTORS

Name of Interviewee: 
Date: 

Background

Can you please give us some overview of your work with regards to international collaboration?
Does your department emphasize collaboration with Canada/developing countries and emerging economies?
What kind of mechanisms do you have to support international collaboration?

Have you supported projects that involve North-South collaboration in health biotech?
Which projects, with whom and in which countries?

Do you feel Canada needs international collaboration with developing countries and emerging economies? (for Canadian interviewees)

What are the main motivations for collaborating with Brazil/India?
Why would Brazil/India want to collaborate with Canada?

Do you think these motivations apply for the field of health biotech?
Do they apply for other countries?

Which countries are good candidates for Canada's/Brazil's/India's collaboration? Why?

In terms of international collaboration with developing countries, do you encourage collaboration in research as well as applied activities? (for Canadian interviewees)

Evaluation

How do you determine which technologies have relevance for Canada/Brazil/India?

What areas do you see Canadian researchers can collaborate with Brazilian/Indian scientists in?

So far what do you see as the main outcomes of Canada's collaboration with Brazil/India? (human resource training, economic impacts, bilateral relations, etc)

So far do you consider Canada’s collaboration with Brazil/India has met its potential? Please justify.
Can you give us examples of successful Canada-Brazil/India collaborations? What are your criteria for a successful collaboration? What factors can increase the chances the international collaboration is successful?

What do you perceive to be the main challenge for collaboration with Canada/Brazil/India? How can they be overcome? Do these challenges apply to other international collaborations?

How do you assist collaborators negotiate sharing of research output? Have any ethical issues been associated with collaboration with Canada/Brazil/India? If so, how have they been dealt with?

How can the potential practical applications from Canada-Brazil/India collaboration be realized? How do you help partners working together to take the project further? Is there an organization/institution in Brazil/India that works with you on how the findings of Canada-Brazil/India collaborative research could be implemented?

What are the main organizations/institutions in Canada/Brazil/India that you work with? How closely do you work with these organizations/institutions? How formalized are your ties with these organizations/institutions? What is the key to successfully work with these organizations/institutions?

**Impacts of programs/policies**

Does Canada-Brazil/India collaboration have relevance for addressing local health needs in Brazil/India (ex: developing or producing medicines, diagnostics or vaccines for the developing world)? Is the project also relevant for other nations? If so, which and in what way?

Does the Canada-Brazil/India collaboration have relevance for innovation in Canada? How about in Brazil/India? How do you think international collaboration can best contribute to innovation and improved global health?

How well do you think Canada's/Brazil's/India's innovation, trade, foreign affairs and aid policies are aligned?

What do you think can be done to strengthen collaboration with Canada/Brazil/India such that it leads to increased innovation and improved global health?
What are your department’s future plans with regards to Canada-Brazil/India collaboration in health biotechnology?

Is there anything else you would like to discuss that you feel is relevant?
Appendix C: Invitation Letter

Dear Sir/Madame,

The purpose of this letter is to invite you to participate in a research project investigating Canada-emerging economies collaboration in the field of health biotechnology. The aim of the research is to examine if and how Canada's health biotechnology collaboration with emerging economies can be advantageous to both parties in terms of economic benefits and strengthening innovation potentials. The research is carried out by the McLaughlin-Rotman Centre for Global Health at the University of Toronto and is supported by a grant from the Canadian Institutes for Health Research.

I would greatly appreciate the opportunity to talk to you about your experiences with collaboration and consult with you about initiatives that could strengthen Canada-emerging economies collaboration in health biotechnology. Your participation in our study would involve meeting with me and sharing your thoughts and insights with regards to promoting sustainable and successful partnerships in the health biotechnology field with partners in emerging economies and developing countries.

Our meeting can take place in your office and should take less than one hour of your time. I would be able to meet with you on the following dates: [X]. Would any of these be convenient for you?

Attached to this email is a summary of the study. A description of the McLaughlin-Rotman Centre for Global Health, University of Toronto can be found at: http://www.mrcglobal.org/home

Should you have any questions, please contact me by email or by phone.

Sincerely,

Monali Ray
Graduate Student
Institute of Medical Science
McLaughlin-Rotman Centre for Global Health
University of Toronto
MaRS Centre, South Tower
101 College Street, Suite 406
Toronto, ON Canada M5G 1L7
Email: monali.ray@utoronto.ca
Phone: 416-673-6555
Appendix D: Papers


