CLIMATE SCIENCE, EQUITY, AND DEVELOPMENT: THE ROLE OF INTERNATIONAL INSTITUTIONS IN CAPACITY BUILDING FOR CLIMATE CHANGE

by

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS OF THE DEGREE OF

MASTER OF SCIENCE

in

The Faculty of Graduate Studies

(Resource Management and Environmental Studies)

THE UNIVERSITY OF BRITISH COLUMBIA

(Vancouver)

August 2012

Abstract

Climate change is a serious global problem that will have a disproportionate impact on developing countries. The ability of these countries to cope depends, at least in part, on the strength of their human capital and institutional capacity related to climate science. This thesis begins by examining the extent to which developing country scientists are participating in global climate science, and then evaluates international efforts to build the capacity of developing country scientists to address the climate change problem. A quantitative analysis of authorship data of the United Nations Intergovernmental Panel on Climate Change (IPCC) assessment reports (1990, 1995, 2001 and 2007) reveals that developing country scientists and institutions remain grossly under-represented – even after normalizing for a number of factors. The IPCC has recently acknowledged this ongoing problem, while the international community has resolved through the United Nations Framework Convention on Climate Change (UNFCCC) process to prioritize capacity building in developing countries. Extensive open source research and interviews with key informants at leading international organizations were used for qualitative purposes to identify, analyze, and evaluate such capacity building efforts. While several impressive initiatives were identified at the regional level, most capacity building activity was isolated and likely to be of limited effectiveness in advancing concerted global action to mitigate and adapt to climate change. The overall conclusion is that the existing international approach to building scientific capacity in the developing world to address climate change is inadequate. Several significant obstacles to achieving sustainable, long-term scientific capacity to address climate change in developing countries are explored, including: institutional barriers, financial issues, the “brain drain” phenomenon, data access and quality, technology and research resource limitations, complexities with downscaling/up-scaling of climate modeling, the interdisciplinary nature of climate change, navigating the science-policy interface, and issues related to operating across culture, language, and gender. Finally, this thesis concludes that the largely ad hoc approach to individual capacity building activities should give way to a more comprehensive, integrated, strategic approach to more effectively build scientific capacity in the developing world to meet the climate change challenge.

Preface

Chapter 1 is my own work, with the exception of the definition of capacity building which is from the following joint-publication: Kandlikar, M., Zerriffi, H., and Ho Lem, C., 2011. Science, decision-making and development: managing the risks of climate variation in less-industrialized countries. *WIREs Climate Change* 2, 201-219. The draft of this article was written by Professor Milind Kandlikar and Professor Hisham Zerriffi, to which I contributed a case study as well as general research assistance and overall editing for the entire document.

Chapter 2 was published in 2011 in an international peer-reviewed journal. Ho-Lem, C., Zerriffi, H., Kandlikar, M. 2011. Who participates in the Intergovernmental Panel on Climate Change and why: A quantitative assessment of the national representation of authors in the Intergovernmental Panel on Climate Change. *Global Environmental Change* 21:4, 1308-1317. I wrote the draft of this chapter including the preparation of all of the tables and figures based on a database that I prepared of authors participating in the four assessment reports of the United Nations Intergovernmental Panel on Climate Change, with the exception of the section dealing with regression analysis. I completed the quantitative analysis, with the exception of the statistical analyses that were completed by Professor Milind Kandlikar with Arvind Saraswat and Nisha Malhotra. Professor Kandlikar and Professor Zerriffi also actively edited the document, selecting data items of most significance, as well as preparing the document for publication.

Chapter 3 is based on a study conducted in accordance with procedures and protocols approved by the UBC Behavioural Research Ethics Board, Certificate of Approval #H08-01857 (Nov 3rd, 2008, renewed). Of the sixteen expert interviews, I conducted fourteen of them while the remaining two were conducted by Professor Milind Kandlikar. I prepared transcripts of the interviews, coded and analyzed the interview data, completed the open source research and literature review, and drafted this chapter. I am grateful for the feedback that I received from Professor Zerriffi and Professor Kandlikar on this chapter and I look forward to working with them in the future to prepare it for publication.

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List of Acronyms

AARC	African Adaptation Research Centres
ACCCA	Advancing Capacity to Support Climate Change Adaptation
ACCFP	African Climate Change Fellowship Program
AEIN	African Environmental Information Network
AIACC	Assessments of Impacts and Adaptations to Climate Change
APN	Asia Pacific Network for Global Change Research
AR4	Fourth Assessment Report of the IPCC
AR5	Fifth Assessment Report of the IPCC
ARCP	Annual Regional Call for Proposals
C3D+	Capacity Development for Adaptation to Climate Change & GHG Mitigation in Non-Annex I Countries
CA	Contributing Author
CAPaBLE	Scientific Capacity Building/Enhancement for Sustainable Development in Developing Countries
CCAA	Climate Change Adaptation in Africa
CIA	Central Intelligence Agency
CLA	Coordinating Lead Author
COP	Conference of the Parties
DC	Developing Countries
DFID	Department for Foreign and International Development (United Kingdom)
EIT	Economies in Transition
EVI	Environmental Vulnerability Index
FAR	First Assessment Report of the IPCC
GCCP	Global Climate Change Program
GCM	General Circulation Models
GDP	Gross Domestic Product
GEO	Global Environmental Outlook
IAI	Inter-American Institute for Global Climate Research
IDRC	International Development Research Centre

IGBP	International Geosphere-Biosphere Programme
IGES	Institute for Global Environmental Strategies
IHDP	International Human Dimensions Programme on Global Environmental Change
IHDW	International Human Dimensions Workshops
IPCC	United Nations Intergovernmental Panel on Climate Change
IRI	International Research Institute for Climate and Society
LA	Lead Author
LOICZ	Land-Ocean Interaction on the Coastal Zone
NGO	Non-Governmental Organization
NSCA	National Self-Capacity Assessment
OLS	Ordinary Least Squares
PPP	Purchasing Power Parity
SAR	Second Assessment Report of the IPCC
SEI	Stockholm Environmental Institute
START	global change SysTem for Analysis, Research and Training
TAR	Third Assessment Report of the IPCC
TWAS	The Academy of Sciences for the Developing World
UN	United Nations
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNESCO	United Nations Economic, Social, and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNITAR	United Nations Institute for Training and Research
US	United States
USAID	United States Agency for International Development
WMO	World Metrological Organization
WCRP	World Climate Research Program
WG	Working Group

Acknowledgments

My co-supervisors, Professor Hisham Zerriffi and Professor Milind Kandlikar, have been outstanding in their support, advice, encouragement, and collaboration. I am indebted to them for their understanding and accommodation of me while I completed this research in the midst of welcoming my first child into the world. I greatly appreciated the opportunity to work on this project and the potential that it brings to improve the global response to climate change, even if in some very small part.

I would like to acknowledge the staff and faculty of the Institute for Resource Management and Environmental Studies, and UBC for funding this research through the Hampton Fund and UBC Graduate Fellowship. I am proud to have been affiliated with such an exceptional institution, faculty, and research project.

The friends that I made through this program have not only been supportive of my academic work, but many have come to be close personal friends that I know I will have for a lifetime. I would like to thank them for their ongoing encouragement and advice. I would also like to thank my family for their support and commitment to seeing me through to completing this degree. In particular, my mom and my sister along with countless other friends provided me with significant childcare support during these last few months so I could finish the write-up of this manuscript. Without such valuable time and assistance from these amazing people, the completion of this project would have been an impossibility.

Finally, I would like to acknowledge my husband for his steadfast presence in everything I do, for I could not have done this without him. I'd like to thank him both for the sacrifices he's made along this journey with me as well as for being an inspiration in my life – I consider myself very blessed to have a partner who wants to change the world as much as I do, and I know we can do great things together, and will keep doing them as long as we can.

For Rivers

1. Introduction

1.1 Overview

The emergence of climate change as a global problem has revealed wide disparities between those responsible for carbon emissions (historically those in industrialized nations) and those who will bear the greatest burden of a more extreme and erratic climate (those in developing countries)[1] (Agrawal and Narain, 1990). Prior knowledge about climate events can render a potential catastrophe into a manageable risk and help identify opportunities for adaptation to a more extreme climate. Scientific capacity to generate appropriate knowledge and the ability to translate that effort into relevant domestic policies is critical for the prevention of, and adaptation to, climate change and can save both lives and livelihoods (Huntingford and Gash, 2005). The science to develop new data and computational tools continues to expand on a global level (IPCC, 2007), but the local capacity to produce and use such knowledge is comparatively low in the developing world, amplifying the disparities discussed above.

A study in 2000 (Sagar) lamented the relative lack of academic literature at the time on the issue of capacity building to address global environmental problems, including climate change. The consequences for developing countries of insufficient scientific capacity are likely to be significant:

> "Even the most rudimentary national policy on climate change requires an assessment of the national and subnational implications of the impacts of climate change and proposed abatement strategies in the context of historical GHG-emitting activities. Countries therefore need to develop a clear understanding of why the climate issue is important for them, and what implication alternative scenarios would have for their national economies. Such studies require a whole range of skills—data collection and analysis, emissions scenarios, climate modeling, impact analysis, and technical and economic analysis of abatement strategies. Unfortunately, there has been almost no attention paid to developing the capacity to perform these functions, to coordinating and utilizing them to formulate national positions and policy proposals, or to doing this in a reiterative manner as the [global climate] negotiations evolve." (Sagar, 2000a)

[1] For the purposes of this paper, developing countries are understood as the 152 countries identified as "Non-Annex 1" countries in the United Nations Framework Convention on Climate Change.

Even in a relatively well-equipped Non-Annex 1 country like India it has been recognized that building a climate science research community faces tremendous hurdles, and that global climate science initiatives are “dominated” by a small number of developed countries (Kandlikar and Sagar, 1999). Soon after Sagar’s dire prognosis in 2000 about the state of scientific capacity to address climate change in developing countries, both the international community and academic literature began to address the concerns raised in the cited study. In 2001, the IPCC’s Third Assessment Report (TAR) was released and has been recognized as being the first assessment report to focus on capacity building to address climate change (Olowa and Olowa, 2011). In the same year, at the Seventh Conference of the Parties (COP 7), “The Marrakesh Accords” included Decision 2/CP.7 on Capacity Building in Developing Countries (Non-Annex I Parties). This decision has been reaffirmed by subsequent COP gatherings as having ongoing relevance and importance. Notably, this decision under the United Nations Framework Convention on Climate Change (UNFCCC) states:

> “…capacity building for developing countries is essential . . . There is no ‘one size fits all’ formula for capacity building. Capacity building must be country-driven, addressing the specific needs and conditions of developing countries and reflecting their national sustainable development strategies, priorities and initiatives… Capacity building is a continuous, progressive and iterative process, the implementation of which should be based on the priorities of developing countries… Capacity-building activities should be undertaken in an effective, efficient, integrated and programmatic manner, taking into consideration the specific national circumstances of developing countries.”

The literature has also evolved since 2000 to recognize that the ability to effectively adapt to climate change, and mitigate its effects, is dependent on adaptive and mitigative capacity, respectively, and that efforts to build such capacity in developing countries must be a priority (Olowa and Olowa, 2011; Pelling et al., 2008; Haddad, 2005; Brooks et al., 2005; Tompkins and Adger, 2005; Smith et al., 2003; Yohe, 2001). The concept of “response capacity” has also been proposed as a means to integrate adaptive and mitigative capacity into a development perspective (Burch and Robinson, 2007). While there is a growing body of literature over the last decade on the theory of capacity building to address climate change and national case studies on the topic, what is missing is a comprehensive empirical account of the state of global capacity building efforts in relation to developing country scientists. Specifically, the literature has neither engaged in a comprehensive analysis of the various strategies and approaches employed by international institutions to building scientific capacity in developing countries, nor identified the challenges and obstacles to such efforts.

1.2 Capacity building

Since "capacity building" is a central concept in this thesis, it is important to briefly describe what is meant by this term. There is a wealth of literature on the general topic of capacity building, which emerged as a significant development concept in the late 1980s. A litany of generalized definitions of "capacity building" or "capacity development" have been proposed both by organizations seeking to undertake such activities as well as by researchers from multiple disciplines (Lusthaus et al., 1999; Horton, 2003; Crisp, 2000). Capacity building and capacity development are often used interchangeably, and depending on the definitions selected for either term, their meanings can be identical or vary widely. Some definitions focus on the actors involved: "capacity is the combination of people, institutions and practices that permits countries to reach their development goals… Capacity building is…investment in human capital, institutions and practices" (World Bank, 1998). However, other definitions conceptualize capacity building as a dynamic and ongoing process: "…an ongoing process by which people and systems, operating within dynamic contexts, enhance their abilities to develop and implement strategies in pursuit of their objectives for increased performance in a sustainable way" (Lusthaus, 1995). "Absorptive capacity" is a related concept that has received widespread interest as it relates to innovation by firms, organizations, and individuals (Cohen and Levinthal, 1990). The concept is of note to those concerned with capacity building since it offers a powerful tool to explain how prior knowledge and background plays an integral role in the extent to which new external information can be effectively adopted.

Given the lack of a consistent definition of capacity building in the literature, and the specific nature of this research project, it is necessary to propose a functional definition that will be of greatest assistance to the context of climate science and developing countries. Scientific capacity could be defined very narrowly in terms of the presence and quality of laboratories and trained personnel, i.e., with an exclusive focus on the production of knowledge. However, such a definition fails to capture ways in which science and society interact, particularly on environmental problems such as climate change, which has a significant public goods component and strong links to development. Goldemberg (1998), drawing on his long experience as one of Brazil's pre-eminent science-policy managers, argues that science for development has multiple dimensions: the ability to modify existing technologies to local circumstances; the capacity for and incentives to work on 'cutting-edge' but locally relevant science; and the direct engagement of science and scientists in policy work. Consequently, this thesis uses a 'systemic' view of scientific capacity for studying the relationship between science and decision-making vis-à-vis climate variation, as one that encompasses knowledge production, as well as its translation for and use in decision-making. This definition of national science capacity includes ways in which science is produced but also translated into usable knowledge and the institutional factors that influence the conduct and use of science (Baud, 2010). A move away from the 'linear model' of science to one that explicitly recognizes feedbacks from translation and use back to production may be particularly important for complex problems of climate and society interactions. The capacity required, as with other environmental problems, includes evaluating the physical environment but also includes understanding the drivers of change and possible responses to change (Sagar, 2000a).

The four functional aspects of scientific capacity (Knowledge Production, Translation, Use, and Feedback) represent actions of actors and institutions that constitute scientific capacity and contribute to its improvement. These functions are understood as follows:

- *Knowledge Production* refers to formal mechanisms by which the scientific community produces knowledge. Here an explicit distinction is made between scientific knowledge and other forms of knowledge such as informal and local knowledge. Formal mechanisms of knowledge production include the accepted ways in which scientific knowledge is generated (e.g., measurement, data analysis, and hypothesis testing), synthesized (modeling and other forms of knowledge integration), and accepted (peer-review and publication processes).

- *Knowledge Translation* refers to the ways in which scientific data and findings are translated into a form accessible to user communities. For example, weather model outputs might need to be converted into probabilistic form, or they may need to be translated into specific instructions (do and don'ts) for particular use communities. Practicing scientists, such as meteorologists, or individuals trained in the sciences such as agricultural extension agents, often do the translation. In industrialized countries, this function is increasingly under the purview of the private sector, while in the developing world this function is primarily provided by government agencies and, in some cases, NGOs.
- *Knowledge Use* refers to ways in which scientific knowledge influences decision-making with regards to climate change and variability. In an applied domain such as climate science, the demand for new knowledge is linked to its uses for policy-making. For example, from the perspective of decision-making under uncertainty, weather forecasts can reduce uncertainty and thereby improve decision-making. Thus, the use of knowledge can establish priorities for scientific research and help in problem definition.
- *Feedback* processes between users and producers of knowledge can help in defining or modifying scientific questions, and help tailor them to the needs of user communities. In the absence of such feedbacks, and demand for new and better information, knowledge production in the developing world can often become isolated in 'Ivory Towers' (Goldemberg, 1998). Feedback processes are different from other functions in that they exist as the set of linkages between the other three functions.

A systems view recognizes that all four elements—Knowledge Production, Translation, Use, and Feedback—contribute to scientific capacity. Capacity development then becomes a *process* that improves the ability of both individuals and organizations to define the problems they face, determine research objectives, and perform the functions necessary to solve problems (Sagar, 2000a; Agrawal, 2008). In other words, in applied contexts with strong policy dimensions such as climate science it is useful to view 'scientific' capacity as a mechanism that both creates the demand for better information and develops the tools and methods to provide it (Sagar and VanDeveer, 2005). This more context-driven or problem-focused view highlights the utility of technical knowledge being 'co-produced' by multi-disciplinary scientific teams in consultation with state agencies and community groups seeking better information (Shackley and Wynne, 1995). 'Boundary' organizations formed to facilitate this process help co-produce knowledge and so are critical in determining the objectives of knowledge production, and its use in decision-making (Guston, 2001)

If scientific capacity building is a process by which both the production of knowledge and the linkages between knowledge production and its use are enhanced, what determines effective scientific capacity? More specifically, what are the factors that shape scientific capacity in the developing world? First and foremost, by definition most developing countries lack financial resources. Budgets for science are small, especially in fields not perceived to have direct economic benefits (Dickson, 2008). Second, the ability to conduct research geared toward particular climate variability problems is hampered by a lack of data, problems with data access, inconsistent data, and uncoordinated data collection efforts. Third, international institutions play a critical role in engaging developing countries in policy discussions in the area of climate and related sciences. This has led to the establishment of capacity building efforts aimed at the ability of developing countries to produce scientific knowledge. Fourth, in many countries of the developing world, linkages between science and policy are sporadic and the processes of feedback between scientific and user communities are weak.

1.3 Research objectives and questions

While the critical need to build scientific capacity in developing countries to address climate change has been recognized (UNFCCC, 2002), as alluded to earlier, the literature has neither (a) engaged in a quantitative assessment of developing country participation in the IPCC, nor (b) provided a comprehensive analysis of the various strategies and approaches employed by international institutions to building scientific capacity in developing countries, and the challenges and obstacles to such efforts. As a result of this, the effectiveness of efforts to meet the challenges facing developing countries related to climate change may be deficient. This study aims to provide an evidence-based foundation for understanding developing country participation in the IPCC, and to contribute to the improvement of international efforts to build scientific capacity in developing countries to address climate change as part of concerted global action to mitigate and adapt to climate change.

This thesis begins by examining the extent to which developing country scientists are participating in global climate science, and then evaluates international efforts to build the capacity of developing country scientists to address the climate change problem. Specifically, Chapter 2 of this thesis examines the participation of developing country scientists and institutions over time in the United Nations Intergovernmental Panel on Climate Change (IPCC). The following research questions are addressed in this chapter:

1) What are the patterns of national participation in the IPCC over time and across types of expertise and authorship?

2) What national socio-economic and/or other characteristics explain these patterns?

3) What does participation in the IPCC tell us about the more general problem of scientific capacity to address the climate problem?

With an understanding of the challenge facing developing countries to both contribute and benefit from global climate science, Chapter 3 identifies, analyzes, and evaluates efforts by international organizations to build the scientific capacity of developing countries. The following research questions are examined in this chapter:

1) How have international institutions shaped the development of national scientific capacity in the developing world to address climate change?

2) What are the challenges, gaps, and drawbacks of these capacity building activities?

3) Should a coordinated response to building scientific capacity to address climate change be pursued? If so, how?

The methodologies employed to address these research questions are described in detail in Chapters 2 and 3, with the former using quantitative analysis whereas the latter relies on qualitative analysis. Further relevant literature is also cited in each of these chapters as it relates to specialized sub-themes examined in them.

Finally, the Conclusion (Chapter 4) identifies the high-level findings that emerge from this study and relate them back to the literature in order to highlight the contribution of this thesis to our knowledge about the challenges and opportunities facing developing countries in addressing climate change. The limitations of the thesis are also acknowledged along with potential applications of this research, and future research questions that this study has raised.

2. A Quantitative Assessment of Participation of Developing Country Scientists in the Intergovernmental Panel on Climate Change

2.1 Introduction

The annual Conference of the Parties (COP15) to the United Nations Framework Convention on Climate Change (UNFCC), held in Copenhagen in December 2009, highlighted the enormous disparity between richer and poorer countries in their perceptions of how to allocate responsibility for addressing the challenge of climate change. A small group of developing countries, including several African nations, walked out during the proceedings over equity concerns (von Bülow, 2009). It was one of many such instances that marked the fractious meetings. These concerns over equitable solutions to the climate change problem are not new. The equity debate surrounding climate change began in the early 1990s (Agarwal and Narain, 1991), and has since continued and intensified (Sagar, 2000b; Pinguelli-Rosa and Munasinghe, 2002; Huntingford and Gash, 2005). The essence of this debate is straightforward: those most responsible for carbon emissions (i.e., past and current residents in industrialized countries) will not likely face the brunt of climate change impacts. That burden will be most felt by current and future residents of the more vulnerable developing world.[2]

The ability of nations to cope with the burden of climate change will be greatly influenced by a number of variables including inter alia economic wealth, institutional capacity and human capital. This paper addresses one specific aspect of human capital, namely scientific capacity. In particular, the scientific capacity required for generating appropriate knowledge and the ability to translate that knowledge into relevant domestic policies is critical for both the prevention of, and adaptation to, climate change and can save both lives and livelihoods (Sagar, 2000a; Huntingford and Gash, 2005). Scientific capacity can be characterized as:

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[2] A report released during the first week of the COP15 ranked the countries of the world most severely affected by extreme weather events (storms, floods, heatwaves, etc.) (Jerichow, 2009; Harmeling, 2009). According to the 2010 Global Climate Risk Index, poorer countries dominate those most affected by extreme weather. Among the ten countries most affected, there is not one developed country, and among the first 20 there are only four developed countries (Italy, Portugal, Spain and the United States).

(1) the effective production and synthesis of knowledge, and

(2) the effective use of climate knowledge enabled by mechanisms for knowledge translation and feedback (Kandlikar et al., 2011).

Mechanisms of scientific knowledge production include data collection (e.g., measurement, data analysis and hypothesis testing), synthesis (modeling and other forms of knowledge integration) and acceptance (through peer-review and publication processes). Knowledge use and feedback refers to the ability to act upon knowledge gained and the ways in which scientific knowledge influences decision-making at various levels. While the IPCC engages in all of these aspects of scientific capacity, this paper focuses on the production of knowledge and its synthesis. Specifically, the international representation of developing countries in the global synthesis of scientific knowledge on climate change is considered through the activities of the Intergovernmental Panel on Climate Change (IPCC). The IPCC has been central in international efforts to consolidate scientific knowledge on climate change, and its efforts are a reflection of existing scientific capacity at a global scale. Consequently, the premise of this paper is that participation in the IPCC provides one quantifiable indicator for the generation, assessment, synthesis and acceptance of knowledge relevant to the understanding of climate change within various countries.

Participation in the IPCC is not the only indicator of science capacity on climate change. Other indicators such as scientific papers on climate published in a country, or the number of per- capita researchers with higher degrees in the climate and related sciences might also be used. However, using participation in the IPCC as our dependent variable vastly simplifies the process of data collection, particularly because the IPCC authorship captures reflects expertise in a wide range of physical, natural and social sciences. Using IPCC authorship as a proxy for capacity might also introduce some biases. In particular, IPCC's global mandate under the auspices of the United Nations might result in greater representation of certain regions over others.

Participation in the IPCC by nations is important for multiple reasons. First, the IPCC operates through an international process where cross-national consensus is an important measure of success. As Farrell et al. (2001) note consensus decision-making can exclude the views of those not present and so can have a direct impact on the legitimacy of an assessment process. Second, given the complex nature of climate change, there is the concern that substantive scientific and policy issues that might be left poorly addressed if the viewpoint of, and analysis by southern researchers is not included (Kandlikar and Sagar, 1999; Lahsen, 2004; O'Neill et al., 2010). Third, the IPCC has been instrumental in setting the policy agenda on climate change policy (Agrawala, 1998b), and its work has become central to creating 'useable knowledge' on climate change (Moss and Schneider, 2000). By design the findings of IPCC assessments feed into negotiations on climate change. Consequently, there are serious equity concerns related to IPCC participation since climate negotiations are inextricably tied to national economic interests (Sagar and Kandlikar, 1997).

The works described above primarily use qualitative data to analyze the role and implications of cross-national participation in the IPCC. This paper by contrast uses quantitative data to analyze participation patterns in the IPCC, and to answer the following questions:

1) What are the patterns of national participation in the IPCC over time and across types of expertise and authorship?
2) What national socio-economic and/or other characteristics explain these patterns?
3) What does participation in the IPCC tell us about the more general problem of scientific capacity to address the climate problem?

It is worth noting here that the term author is used to denote all experts – natural scientists and social scientists alike. While the unit of analysis is authors, the IPCC vets an authors expertise, thus all authors can be considered experts within their field. This expertise may either be in the natural or in the social sciences, and for the purposes of this paper, scientific capacity encompasses both. In other words, what is being discussed is the capacity to engage in rigorous analytical research in a climate change related domain, whether it be meteorology or economics. This reflects the IPCC's own view, whereby all authors are considered "scientists" regardless of domain of expertise. Throughout this paper the terms "scientist" and "science" should, therefore, not be read to mean only the natural sciences.

This paper addresses the three above questions using cross- national data on the participation of scientists in the IPCC process. Section 2 provides a brief overview of the IPCC, with a particular focus on issues of global participation. Section 3 presents a description of cross-national patterns of participation in the IPCC sorted by region, country, economic and demographic indicators, scientific domain and trends over time (Question 1). In Sections 4 and 5, statistical analyses are performed using generalized linear models to quantitatively estimate the effect of a number of socio- economic, environmental and procedural factors influencing country-level participation in the IPCC (Question 2). The analysis accounts for a number of the other factors known to influence scientific capacity (e.g., level of economic wealth, education levels). The paper concludes in Section 6 with a discussion of the potential significance of the findings for scientific capacity and coping with climate change in the developing world (Question 3).

2.2 The IPCC: a brief overview

The IPCC was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 as a scientific body with a mandate to review and assess the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change (IPCC, 2010a). Thousands of scientists from all over the world contribute to the IPCC, and although it does not directly conduct research or monitor climate-related data or parameters, the IPCC provides an indispensible role in synthesizing global knowledge with the aim of delivering an objective and complete assessment of current information (Agrawala, 1998a). As an intergovernmental panel, the IPCC is open to all member countries of the UN (192 member states) and the WMO, with consensus- based decision making guiding activities such as work programme direction, senior administration elections, and the acceptance, adoption and approval of reports.

The preparation of the Assessment Reports on Climate Change is a key contribution of the IPCC towards a clear, scientific understanding of climate change. There have been four Assessment Reports to date: 1990 (FAR), 1995 (SAR), 2001 (TAR) and 2007 (AR4), with work towards a fifth report currently in progress. Each report has three main sections delineated by a separate Working Group (WG): WG I assesses the physical scientific aspects of the climate system and climate change; WG II assesses the vulnerability of socio-economic and natural systems to climate change, negative and positive consequences of climate change, and options for adapting to it; and WG III assesses options for mitigating climate change (IPCC, 2010b). Each chapter of the report has one or more Coordinating Lead Authors (CLAs) coordinating the content of each chapter (IPCC, 2010c). Lead Authors (LAs) work in teams to produce content for chapter sections, and are often supported by Contributing Authors (CAs) who provide technical information on specific subjects covered by each chapter.

The IPCC is a hybrid organization comprised technical experts with a mandate to provide scientific advice to a consensus-based international political process. Concerns about national representation within the IPCC have been expressed since its inception. IPCC's founding chairman the Bert Bolin was reported to have said "Right now, many countries, especially developing countries, simply do not trust assessments in which their scientists and policymakers have not participated. Don't you think credibility demands global representation?" (Schneider, 1991). Consequently, broad participation of scientists from different nations is desirable and perhaps needed for its legitimacy (Sagar and Kandlikar, 1997; Lahsen, 2004; Biermann and Frank, 2002). Over time, the IPCC has made some efforts to improve developing country representation. In 1993, IPCC rules were changed to require "at least one and normally two or more" LAs and CLAs for each chapter to be from a developing country (IPCC, 2010c). Additionally, the chairmanship of each working group is required to be shared between one developing and one developed country author (Agrawala, 1998b). While there are specific rules on the national representation for CLAs and LAs and Chairpersons for the working groups, LAs and CAs are typically incorporated into the writing team through an informal process of invitation by a chapter's coordinating authors. The IPCC makes additional efforts to include developing country expert participation in its workshops by providing funding for travel to meetings via the IPCC trust fund, and inclusion in authorship and review processes. These efforts notwithstanding, as shown below, equitable representation of scientists from developing countries in the IPCC is a distant goal.

2.3 Patterns of participation in the IPCC

Although the IPCC has contributed to a wealth of reports and technical assessments to inform climate change policy, this study is limited to examining participation in the four existing IPCC Assessment Reports (IPCC, 2009a). These reports are the primary output of the IPCC and provide a comprehensive data set of author participation across countries and over time. A database of authorship and nationality was constructed for each of the 4494 IPCC authors in the four reports.[3] Authorship type (CLA, LA, or CA) was also recorded for each entry. The patterns of representation across different types of scientific expertise were analyzed by examining participation in the three Working Groups (WGs): WGI Scientific Basis; WGII Adaptation; and WGIII Mitigation. Authors were counted independently for each report so in the event that an author contributed to more than one report, they are counted separately for each effort. Finally, if an author was designated as being from more than one country, each country was represented as fraction in the database (e.g., if an author was from two countries, each country would be assigned a value of 0.5 instead of a 1).

Country assignments were based upon on those identified by the IPCC and so may not necessarily reflect a scientist's country of origin but rather the country/institute where they are currently residing or working. While this is likely to result in a lower count for developing country authors due to patterns of academic mobility, it is impossible to determine national origins without making problematic assumptions. For example, how would objectively one classify an author born and raised in India, trained in the US and

[3] Of a total 4494 of authors to the four IPCC reports, there were 115 authors (2.6%) whose country affiliations were not listed and are unknown. 81% of these unaffiliated authors were involved with three chapters of WGII in the First Assessment Report from 1990. This was a time preceding the UNFCCC when participation by countries later recognized as ''Non-Annex 1'' was minimal. It is unlikely that non-inclusion of these authors in the subsequent analysis has substantial bearing on the results.

with US citizenship, who currently works in Canada? Similarly, it would not be appropriate to assume that authors from one country that work in another may (or may not) contribute to the scientific capacity of their country of origin. Further, some authors from industrialized countries spend considerable time working in developing countries and contributing to the scientific capacity of those countries. The most defensible way to classify such individuals would be through self-identified affiliation. Therefore, while imprecise, self-identified country affiliations as reflected in the IPCC reports are the most defensible way to assign national representation.

The broad patterns of national participation found in the IPCC reports are described and illustrated below, identifying representation by region and country as well as across types of expertise (i.e., working group) and authorship. However, as discussed above, the capacity to participate in the process varies widely between countries. Two preliminary measures of a country's capacity are its economic capital and human capital. Countries with larger economies can provide greater funding for research and engage in international efforts such as the IPCC; while countries with larger populations should, in theory, have a larger base from which to draw IPCC participants with the necessary training. Therefore, authorship counts by country and continent were also normalized by Purchasing Power Parity-adjusted Gross Domestic Product (GDP-PPP) and population in order to further facilitate comparisons between countries and regions. Finally, changes in author- ship over time between Annex 1 (developed) and Non-Annex 1 (developing) countries as defined by the United Nations Frame- work Convention on Climate Change (UNFCCC, 1992) are presented; Annex 1 and Non-Annex 1 countries serve as proxies for developed and developing countries, respectively.

2.3.1 Regional and geographic distribution

The countries of North America and Europe account for roughly three-quarters of all IPCC authors in the four IPCC reports (37% and 36%, respectively); with Asia (10%), Oceania (7%), Africa (4%) and South America (3%) accounting for the rest (Table 2.1). Author representation within Annex 1 (developed) countries is dominated by the United States (1357 authors; 31% of total authors), which is almost double the sum total of all

Non-Annex 1 authors (690 authors; 16% of total authors). Annex 1 countries had a higher representation than Non-Annex 1 countries within each of the three Working Groups. Annex 1 countries also had a higher representation than Non-Annex 1 countries within each of the three authorship categories: Contributing Lead Author (CLA), Lead Authors (LA), and Contributing Authors (CA) (Figure 2.1).

Among the top-10 contributing countries to all four IPCC reports, the most significant numbers of scientists are in WGI (the Scientific Basis), rather than in WGII or WGIII (Table 2.1). Conversely, when the contributions of the top-10 countries to the four IPCC reports are set aside, the majority of contributions from the remaining countries are predominantly active in Working Group II: Impacts and Adaptation. A closer look into the chapters of a single report (WGII in the 2007 Report) reveals interesting patterns (Figure 2.2). While the mean proportion of representation of Non-Annex 1 authors is roughly 20%, the chapters on adaptation in Africa, Asia and Latin America have almost exclusive involvement of Non-Annex 1 authors (75%, 70% and 100% Non-Annex 1, respectively). Conversely, some chapters involve few or no Non-Annex 1 Authors (such as the chapters on impacts and adaptation in Australia and New Zealand, North America, Europe and the Polar regions).

Table 2.1 Selected data on authors of the IPCC Assessment Reports (1990-2007)

Annex 1	Rank	Country of Author	Number of Authors	Working Group I Authors	Working Group II Authors	Working Group III Authors	Coordinating Lead Authors	Lead Authors	Contributing Authors	Percentage of total (known) authors
By Country (top 30)										
✓	1	United States	1356.5	857	345.5	154	82	264.5	1010	31%
✓	2	United Kingdom	503	300	168	35	43	95.33	364.66	11%
✓	3	Germany	271.5	189	59.5	23	14	46	211.5	6%
✓	4	Canada	254.16	113.16	112	29	13.5	71.33	169.33	6%
✓	5	Australia	249.83	131.33	106.5	12	17.5	50	182.33	6%

Table 2.1 Selected data on authors of the IPCC Assessment Reports (1990-2007)										
Annex 1	Rank	Country of Author	Number of Authors	Working Group I Authors	Working Group II Authors	Working Group III Authors	Coordinating Lead Authors	Lead Authors	Contributing Authors	Percentage of total (known) authors
✓	6	Japan	153	65	50	38	13	54	86	3%
✓	7	France	140.68	89.18	29	22.5	8	40.84	91.84	3%
✓	8	Netherlands	133	41	47	45	14.5	39.5	79	3%
✓	9	Russia	123	59.5	50	13.5	11	34.5	77.5	3%
×	10	China	112.5	44	43	25.5	9	50	53.5	3%
✓	11	Switzerland	111.5	69.5	38	4	8	13	90.5	3%
×	12	India	100.5	23.5	42	35	16	42	42.5	2%
✓	13	New Zealand	78	17.5	52.5	8	9	16.5	52.5	2%
✓	14	Norway	58.5	35.5	13	10	3	13.5	42	1%
×	15	Argentina	47	9	33	5	2	20.5	24.5	1%
×	16	Brazil	45.5	13.5	15	17	6	23.5	16	1%
✓	17	Sweden	44.5	21.5	19	4	6.5	8.5	29.5	1%
×	18	Kenya	36	9	24	3	1	21	14	1%
×	19	South Africa	32.5	7.5	18	7	4	9	19.5	1%
×	20	Mexico	30.5	2.5	21	7	4	17.5	9	1%
✓	21	Belgium	30	20	7	3	0	9.5	20.5	1%
✓	22	Denmark	28.5	10	10	8.5	3	11	14.5	1%
✓	23	Finland	27.5	7.5	14	6	4	8	15.5	1%
✓	24	Italy	27	12.5	7.5	7	1	10	16	1%
✓	25	Austria	26.5	6	9	11.5	0.5	10	16	1%
×	26	Nigeria	19	3	12	4	1	8	10	<1%
✓	27	Spain	18.5	6.5	10	2	1	3	14.5	<1%
×	28	Peru	14.5	0.5	11	3	0	5.5	9	<1%

Table 2.1 Selected data on authors of the IPCC Assessment Reports (1990-2007)

Annex 1	Rank	Country of Author	Number of Authors	Working Group I Authors	Working Group II Authors	Working Group III Authors	Coordinating Lead Authors	Lead Authors	Contributing Authors	Percentage of total (known) authors
✗	29	Bangladesh	14	0	12	2	4	5	5	<1%
✓	30	Hungary	14	0	10	4	2	5	7	<1%
		Country of origin Unknown	115	2	113	0	12	20	83	2.6%
By Continent										
		Africa	167	28.5	103	35.5	14	83.5	54.5	3.7%
		Asia	465	142.5	203	119.5	44	190	193.5	10.3%
		Europe	1600.5	876.01	519	205.5	92	359.67	970.84	35.6%
		North America	1673.66	975.66	504	194	86.5	360.83	1054.83	37.2%
		South America	140	26.5	79	34.5	11	69.5	53.5	3.1%
		Oceania	332.83	148.83	164	20	24.5	68.5	209.83	7.4%
Annex 1 vs. Non-Annex 1										
		Annex 1 Countries	3689.5	2060	1183.5	446	257.5	820	2612	84%
		Non-Annex 1 Countries	689.5	138	388.5	163	80.5	328	689.5	16%
Total for all countries			***4494***	***2200***	***1685***	***609***	***350***	***1168***	***2976***	***100%***

Figure 2.1 IPCC Assessment Report (1990–2007) authors from Annex 1 vs. Non-Annex 1 countries across types of expertise

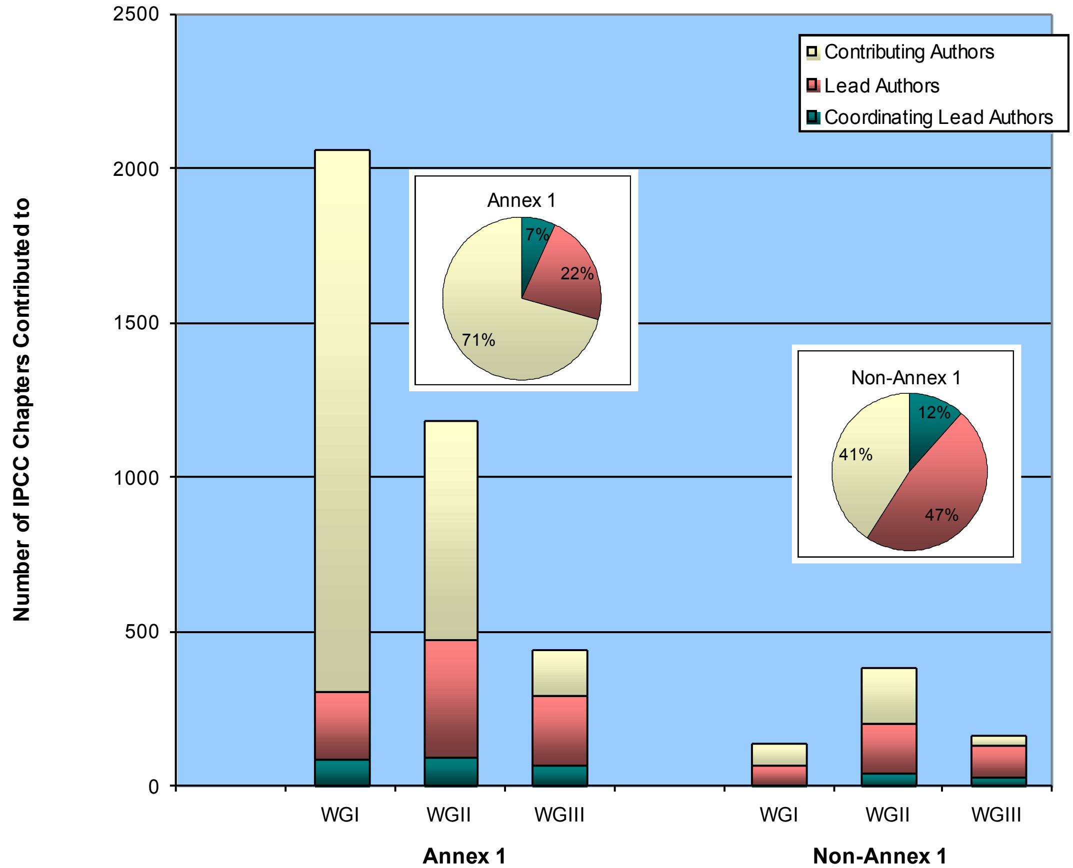
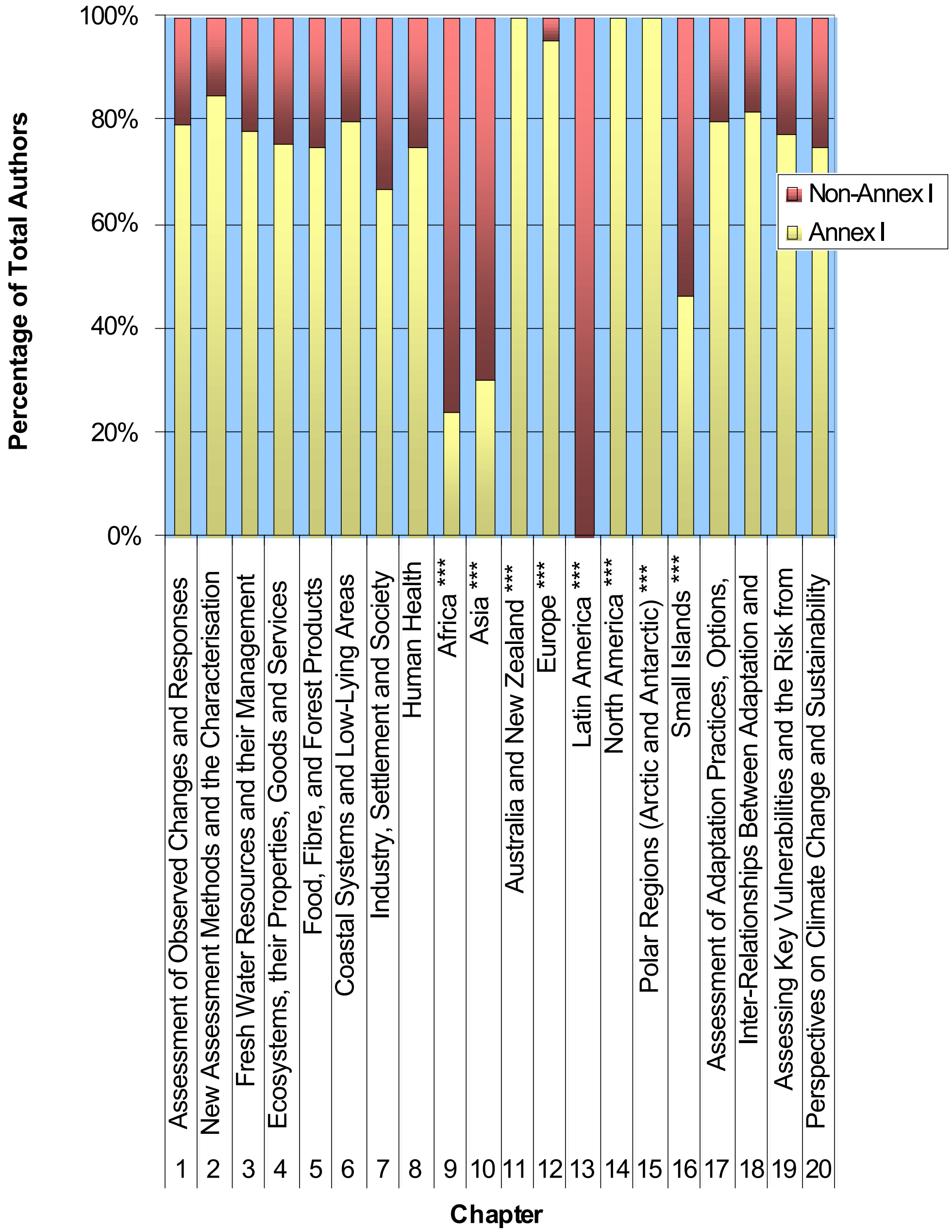


Figure 2.2 Annex 1 vs. Non-Annex 1 authors of the IPCC Working Group II report

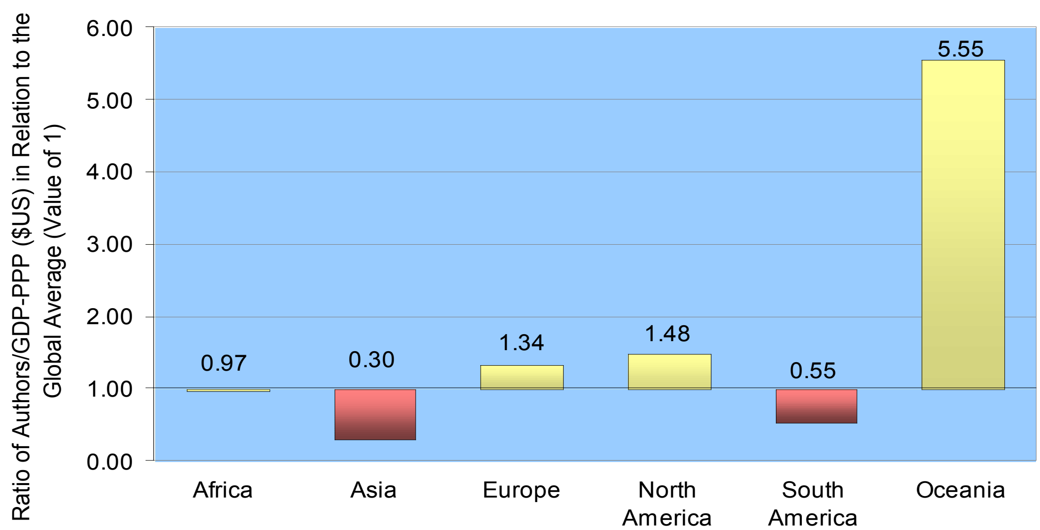


2.3.2 Data normalized by GDP

To facilitate comparisons between countries with vastly different levels of economic activity, data for national and continental participation in the IPCC reports was normalized by GDP-PPP value in US Dollars for each country/continent using figures from the CIA World Fact book from 2008 or the alternate most recent estimates collected

(CIA, 2009). An ‘‘authorship per GDP-PPP dollar’’ metric for each country was thus created. The global average authors per $GDP-PPP value was 63.21 authors/ $trillion GDP-PPP. The relative participation of authors by continent is as follows: Europe (1.34 times the global average); North America (1.48); and Oceania (5.55) were all represented at a rate higher than the global average (Figure 2.3). Conversely, Asia (0.30), South America (0.55) are underrepresented while Africa (0.97) performs roughly on par with the global average despite its less- industrialized economy.

Figure 2.3 Total authors/GDP-PPP by continent in proportion to the global average for the IPCC Assessment Reports (1990–2007)



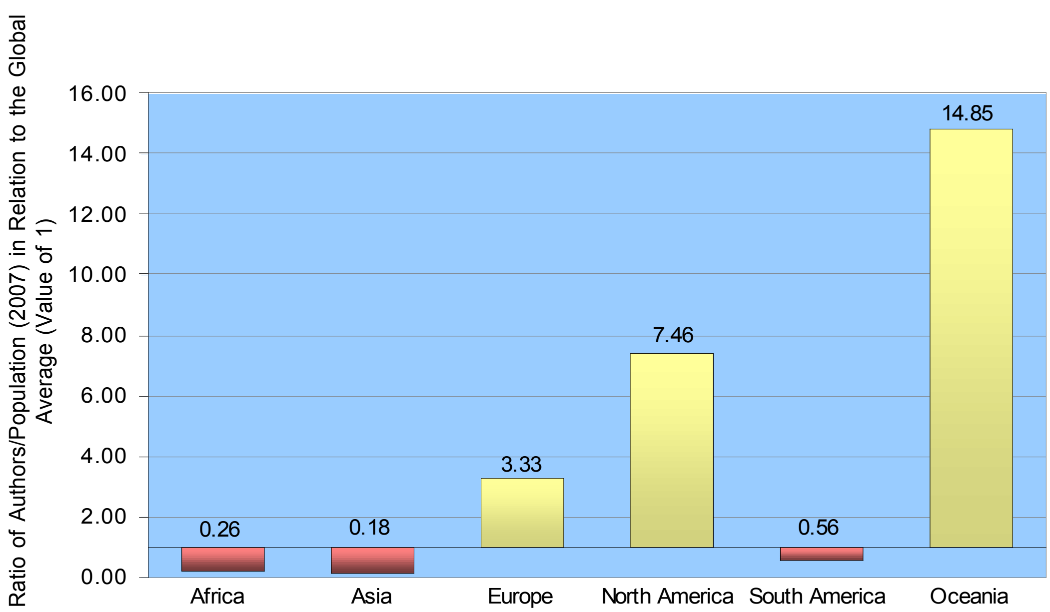
The high value for Oceania reflects the fact that 98.5% of the authorship contributions from the region are from Australia and New Zealand, both with established scientific infrastructure but with relatively smaller economies as compared to other developed economies. Another factor is the English speaking status of these countries (explored further in Section 2.5). However, there may be other factors at play given the level of over-representation of Australia and New Zealand in the IPCC. For example, Australia is a climatically vulnerable country that in recent times has faced prolonged droughts (Ummenhofer et al., 2009). Consequently it invests heavily in applied research on climate variability and change; it is also a major exporter of coal and so mitigation research is also strongly in its national interest. In contrast with the large presence of Australians and

New Zealanders in the IPCC, there were only five authors from all other countries of Oceania (representing Fiji, Papua New Guinea and Samoa) over the four reports.

2.3.3 Data normalized by population

Participation in the IPCC reports was normalized using 2007 population values retrieved from the United Nations Statistics Division (UN, 2009). An ‘‘authorship per capita’’ metric for each country was thus created. Relative to the global average author's per capita value of 66 authors/100 million residents, Europe (3.33 times the global average); North America (7.46); and Oceania (14.85) were all represented at a rate higher than the global average (Figure 2.4). Conversely, countries of Africa (0.26), Asia (0.18) and South America (0.56) were all substantially underrepresented when compared with the global average. These patterns are hardly surprising, given the low representation of Annex 1 country authors within these regions. As above, Oceania is over-represented due to large levels of participation from countries with relatively small populations, namely Australia and New Zealand. Considering Oceanic nations separately, small island nations (i.e., not Australia and New Zealand) have a relative participation rate of 0.84, while the participation rate of Australia and New Zealand rises to 20 times the global average.

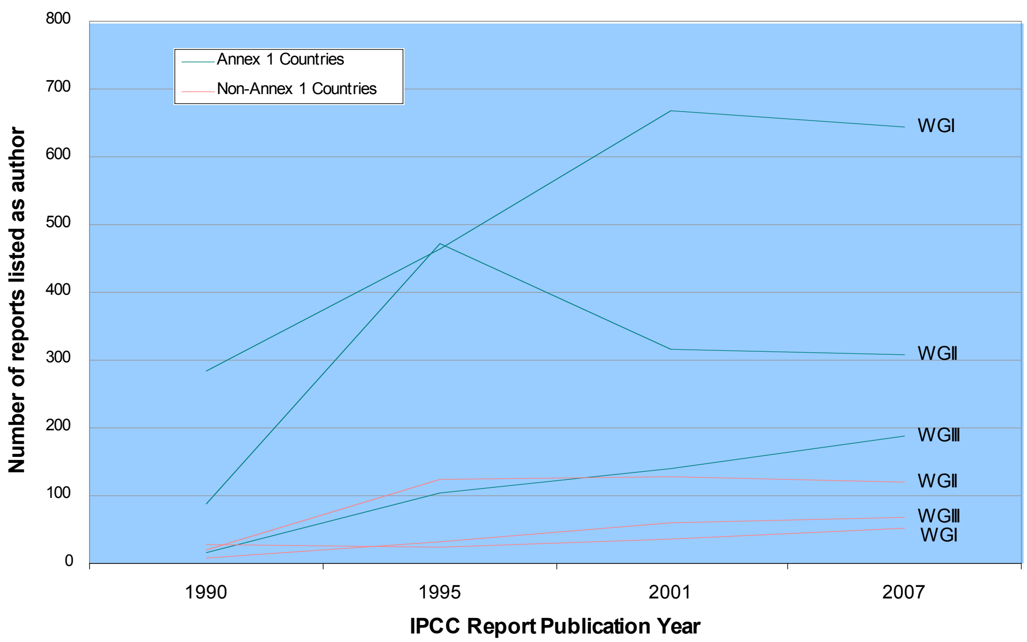
Figure 2.4 Total authors/population by continent in proportion to the global average for the IPCC Assessment Reports (1990–2007)



2.3.4 Authorship trends

The total number of IPCC authors in each working group has grown significantly since the first report in 1990 (Figure 2.5). Annex 1 authors approximately tripled over this time (from a total of 387 in 1990 to 1143 in 2007), while Non-Annex 1 contributions more than quadrupled (52–238). Annex 1 countries accounted for 88% of all 1990 report authors, decreasing to 83% of total authors in 2007. Conversely, Non-Annex 1 authors represented 12% of all 1990 report authors, growing to 17% of total report authors in 2007. This increase of Non-Annex 1 authors over time is primarily due to an increase in contributions to WGII.

Figure 2.5 Authorship by Working Group from Annex 1 and Non-Annex 1 Countries contributing to the IPCC Assessment Reports over time



Within WGI, both Annex 1 and Non-Annex 1 authors doubled between 1990 and 2007. Annex 1 authors increased from 284 in 1990 to 645 in 2007. Likewise, Non-Annex 1 WGI authors increased from 26 in 1990 to 52 in 2007, representing approximately 8% of total WGI authors across this time period. In WGII, Annex 1 authors increased from 87 in 1990 to 310 in 2007, representing a relative decrease from 82% to 72% of total WGII authors, respectively. With respect to Non-Annex 1, authors increased in WGII from 19 in 1990 to 119 in 2007, representing a relative increase from 18% to 28% of total WGII authors, respectively. This is largely because of Non-Annex 1 representation in regional impacts and adaptation chapters. Finally, in WGIII, Annex 1 countries contributed 16 authors in 1990, growing to 189 authors in 2007. Non-Annex 1 WGIII authors increased from 7 to 68 in the same period. Even though overall authorship counts increased over time for both Annex 1 and Non-Annex 1 countries, over this period the relative proportion within WGIII shifted in favour of Annex 1 countries (from 70% of all WGIII authors in 1990 to 74% in 2007) (Table 2.2).

Table 2.2: Trend analysis of IPCC authors within working groups

	1990 Authors (% of total 1990 authors)	**1995** Authors (% of total 1995 authors)	**2001** Authors (% of total 2001 authors)	**2007** Authors (% of total 2007 authors)	**Total Reports**
Total Authors					
Annex 1 Total Authors	**387 (88%)**	**1040 (86%)**	**1121 (83%)**	**1143 (83%)**	**3690**
Non-Annex 1 Total Authors	**52 (12%)**	**176 (14%)**	**225 (17%)**	**238 (17%)**	**690**
Working Group I					
Annex 1 WGI	284 (65%)	464 (38%)	668 (50%)	645 (47%)	2060
Non-Annex 1 WGI	26 (6%)	24 (2%)	37 (3%)	52 (4%)	138
Working Group II					
Annex 1 WGII	87 (20%)	472 (39%)	315 (23%)	310 (22%)	1184
Non-Annex 1 WGII	19 (4%)	122 (10%)	129 (10%)	119 (9%)	389
Working Group III					
Annex 1 WGIII	16 (4%)	104 (9%)	138 (10%)	189 (14%)	446
Non-Annex 1 WGIII	7 (2%)	30 (2%)	59 (4%)	68 (5%)	163
TOTAL	**438**	**1216**	**1345**	**1380**	**4379**

The number of IPCC authors in each authorship category (CLA, LA and CA) has grown significantly since the first report in 1990 (Figure 2.6, Table 2.3). While Annex 1 CLAs increased from 55 in 1990 to 64 in 2007, their relative participation within the total group of CLAs decreased from 83% to 67%. Conversely, Non-Annex 1 CLAs increased both in absolute terms from 11 to 32, and in relative terms from 17% to 33% of all CLAs over the same period. While Annex 1 LAs increased from 16 authors in 1990 to 271 in 2007, their relative participation within the total group of LAs declining from 100% to 68% during this period. On the other hand, Non- Annex 1 LAs increased from no authors in 1990 to 125 authors in 2007, representing a relative increase in participation from 0% to 32% of total LAs over this period.

Figure 2.6 Authors by authorship type from Annex 1 and Non-Annex 1 countries contributing to the IPCC Assessment Reports over time

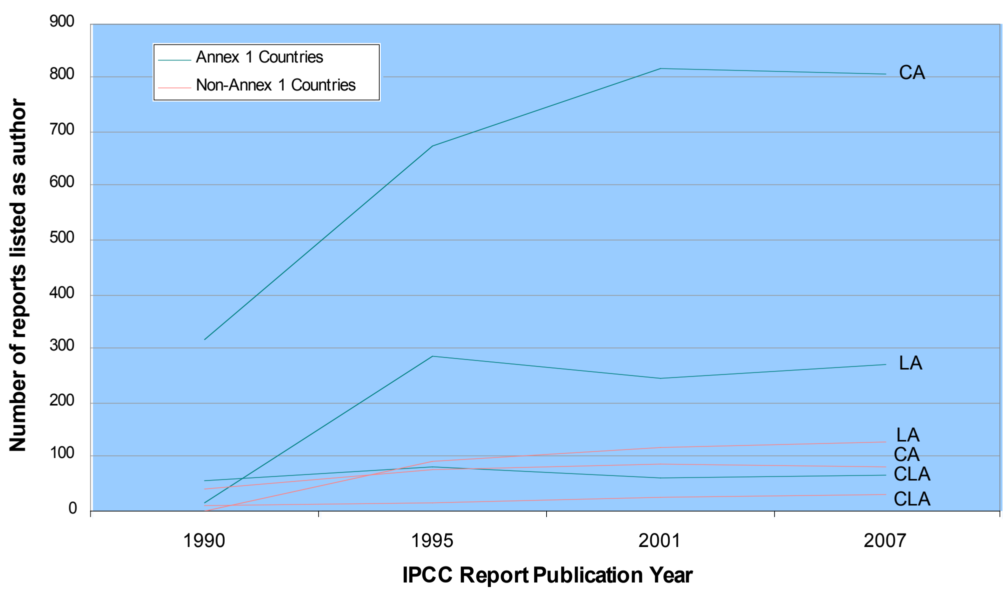


Table 2.3: Trend analysis of IPCC authors by authorship type					
	1990 Authors (% of total 1990 authors)	**1995** Authors (% of total 1995 authors)	**2001** Authors (% of total 2001 authors)	**2007** Authors (% of total 2007 authors)	**Total Reports**
Annex 1 Countries					
Total Authors	**387 (88%)**	**1040 (86%)**	**1121 (83%)**	**1143 (83%)**	**3690**
CLA	55 (13%)	80 (7%)	59 (4%)	64 (5%)	258
LA	16 (4%)	287 (24%)	247 (18%)	271 (20%)	820
CA	316 (72%)	673 (55%)	815 (61%)	809 (59%)	2612
Non-Annex 1 Countries					
Total Authors	**52 (12%)**	**176 (14%)**	**225 (17%)**	**238 (17%)**	**690**
CLA	11 (3%)	14 (1%)	24 (2%)	32 (2%)	81
LA	0 (0%)	89 (7%)	115 (9%)	125 (9%)	328
CA	41 (9%)	73 (6%)	86 (6%)	81 (6%)	281
TOTAL	438	1216	1345	1380	4379

Increases in LA and CLA participation are partly a consequence of IPCC rules that require at least one lead from a developing country. In contrast to CLAs and LAs, Contributing authors (CAs) are not formally selected by the IPCC secretariat; they are brought into the assessment panel informally as co-authors and writers at the invitation of CLAs and LAs. CAs comprises roughly two-thirds of the total number of authors in our data set; of these an overwhelming majority (almost 60% of total authors and 90% of all CAs) belong to Annex 1 countries.[4] Additionally, participants in WGI are by far the

[4] In terms of absolute participation, the Annex 1 CAs are by far the most significant contributor in number to all the reports (2976 authors; 68% of all known authors). However, because the role of CAs is relatively less influential than CLAs and LAs, consideration of all three author types may distort the actual impact of Annex 1 vs. Non-Annex 1 country scientists. Even once the CAs are removed from consideration, however, while the relative gap between Annex 1 and Non-Annex 1 country participation is reduced, Annex 1 authors are still more frequently involved as CLAs and LAs compared to Non-Annex 1 countries.

largest group of CAs (1822 authors) comprising approximately 60% of the total CA contributions.

2.4 Explaining variation in cross-national participation in the IPCC

In the previous section, we presented data on patterns of national authorship in the IPCC. In this section we try to explain these patterns through an analysis of the underlying country-level socio-economic variables. The statistical models presented here use socio-economic characteristics as independent variables to help explain country-level authorship counts. Also included are other independent variables linked with vulnerability to climate change and the UNFCCC process that might influence participation. The dependent variable used to characterize participation of a country in the IPCC is the total number of authors from that country in all four reports irrespective of working group, or type of authorship. Such an aggregate measure captures several key aspects of participation. Aggregating across working groups captures the extent to which a country is engaged in all aspects of climate change. Aggregating across types of authors captures both the political process by which LAs and CLAs are assigned, but importantly captures the informal networks of expertise through which CAs are included in the IPCC's writing process, without explicit policy intervention. Thus, aggregating across different authorship types captures the multiple ways in which participation is determined. Finally, aggregating participation of a country over time presents a long-term picture of participation and smoothes over outcomes that are particular to a specific assessment report.

2.4.1. Socio-economic variables

The socio-economic variables were chosen to reflect scale effects resulting from size of the economy and population (Gross Domestic Product based on Purchasing Power Parity or GDP-PPP, and population), higher education (tertiary education levels), and linguistic ability to participate in international discussions (English- speaking status).

GDP-PPP and population both reflect the hypothesis that richer and more populous countries have greater financial and human resources and so show greater propensity to participate. As above, estimates for 2008 GDP adjusted for Purchasing Power Parity (PPP) (or the alternate most recent estimates) were collected from the CIA World Factbook (CIA, 2009), while the 2007 population figures were retrieved from the United Nations Statistics Division (UN, 2009).

English is the operational language of the IPCC and is also the global language of science. A lack of facility in English is likely to be a significant barrier to engagement in climate science as well as participation in the IPCC. This effect was captured using a dummy variable for English-speaking nations. A list of countries where English is an official language was compiled from a variety of sources, including The CIA World Factbook, and encompasses sovereign states and territories where English is one of any number of official languages and also those where English is the dominant language but does not have official status (Wikipedia, 2009).

Higher education levels serve as a proxy for scientists trained in fields of research that form a part of climate assessment. These were captured by using the proportion of the population 25 years or older that had ever enrolled in tertiary (post-secondary) studies (Barro and Lee, 2000). Missing data for some countries was augmented by UNESCO data on tertiary enrolments (UNESCO, 2009). In the small number of cases where 2007 data was unavailable, the most recent prior data on tertiary enrolments was used.[5]

2.4.2. Climate change vulnerability variable

Climate change impacts were captured using the Environmental Vulnerability Index (EVI). The EVI was developed by the South Pacific Applied Geoscience Commission,

[5] For countries missing tertiary enrolment data from Barro and Lee (2000), their data points were filled in using the following process: Raw data from UNESCO on the total number of tertiary enrolments (UNESCO, 2009) was collected and then divided by the population (2007) data (UN, 2009) in order to obtain a percentage value. These countries included: Albania, Andorra, Angola, Armenia, Azerbaijan, Bahamas, Belarus, Bhutan, Bosnia and Herzegovina, Burkina Faso, Cambodia, Cape Verde, Chad, Comoros, Côte d'Ivoire, Djibouti, Eritrea, Gabon, Georgia, Grenada, Guinea, Guinea-Bissau, North Korea, Kyrgyzstan, Laos, Lebanon, Liechtenstein, Luxembourg, Macedonia, Madagascar, Maldives, Marshall Islands, Micronesia, Monaco, Mongolia, Montenegro, Morocco, Nigeria, Oman, Palau, Qatar, San Marino, Sao Tome and Principe, Saudi Arabia, Serbia, Somalia, Sudan, Tanzania, Timor-Leste, Tonga, Turkmenistan, Ukraine, Uzbekistan, Vanuatu, and Yemen. For the small number of cases for which 2007 data on tertiary enrolments was unavailable, the most recent prior data available was used along with the population figures for that corresponding year, taken from the UN Statistics Division (UN, 2009).

with support from the United Nations Environment Program (EVI, 2009). The EVI incorporates vulnerability of nations across a range of environmental impacts, ranking nations on a scale of 0–7; here the sub-category for climate change impacts was used to capture national vulnerability to climate change. Many indicators representing the complexity of this vulnerability were used to generate the index including: renewable water resources, precipitation patterns, winds and storms, sea temperature, habitat diversity and fragmentation, species introductions and area at risk to sea level rise including coastal settlements and human population density.

2.4.3. Process variables

We use two proxies for engagement in the UNFCCC and IPCC processes as possible explanations for increased authorship in the IPCC. The first, the level of "common but differentiated" responsibility towards solving the climate problem in the UNFCCC, is captured using a dummy variable for Annex 1 country classification (UNFCCC, 1992). Further, engagement in the IPCC process is also captured as the "IPCC effect" using count data for the nationality of chairpersons and administrators in each IPCC working group. These were identified through listings in each of the four IPCC reports (for each year there were 1–2 chairpersons/ administrators per working group); we hypothesize that this variable might be expected to increase participation in the IPCC from the countries that the administrators represent.

2.5 Discussion of results

The descriptive statistics shown in Section 3 demonstrate large variations in levels of participation across countries and regions. Nationals from a substantial fraction of countries all of them Non-Annex1 (45%) have *never* participated in the IPCC process as an author.[6] Among those countries with non-zero participation, levels vary by more than

[6] The list includes the following countries: Afghanistan, Albania, Andorra, Angola, Armenia, Aruba, Azerbaijan, Bahrain, Belarus, Belize, Bhutan, Bosnia and Herzegovina, Brunei, Burundi, Cambodia, Cameroon, Cape Verde, Central African Republic, Comoros, Côte d'Ivoire, Croatia, Cyprus, Democratic People's Republic of Korea, Democratic Republic of Congo, Djibouti, Dominica, Dominican Republic, El Salvador, Equatorial Guinea, Eritrea, Estonia, Gabon, Georgia, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Iraq, Jordan, Kiribati, Kuwait, Kyrgyzstan, Latvia, Lebanon, Lesotho, Liberia, Libya, Liechtenstein, Luxembourg, Macedonia, Madagascar, Maldives, Marshall Islands, Mauritania, Federated States of Micronesia, Myanmar, Namibia, Nauru, Oman, Palau, Panama, Paraguay, Republic of

three orders of magnitude across countries. Even among the top 30 countries, levels vary by two orders of magnitude, as shown in Table 2.1. Such a skewed distribution of counts makes it difficult to use Ordinary Least Squares (OLS) techniques; the residuals tend to be heteroskedastic, with significant positive and negative outliers. Consequently, regression models for count data generally assume that the response variable has a Poisson distribution (Cameron and Trivedi, 1998). Addition- ally, when the variance of the response variable far exceeds its mean (as is the case here) the standards errors on coefficients are biased and too small when Poisson models are used. In such cases, count data best follows a negative binomial distribution (Hilbe, 2007).

Negative binomial regression models are more general models than the Poisson, and similar to a mixture of Poisson distributions. Specifically, in a negative binomial distribution, the underlying rate of events is Poisson whose mean rate λ_i, is gamma distributed (mean λ_i and variance λ_i^2/r). The parameter r is called the over dispersion parameter, and helps model the high variations in count data; as r approaches infinity, the negative binomial distribution follows the Poisson form. Model fits are determined by a pseudo R-squared ratio that uses a likelihood measure to evaluate the improvement from the null model to a fitted model (Nagelkerke, 1991; Cragg and Uhler, 1970). We perform regressions for three types of count data: IPCC authorship for both Annex 1 and Non-Annex 1 countries, with a dummy variable to indicate Annex-1 membership (Model 1); IPCC authorship for Annex 1 countries alone (Model 2); IPCC authorship for Non-Annex 1 members alone (Model 3). Splitting the population into Annex 1 and Non-Annex 1 countries helps assess significant drivers for participation within these groups. In addition, we also run different versions of Model 3 (Models 3a through 3e) with dummy variables that capture the effect of regional groupings of Non-Annex 1 countries (Latin America, Asia, Africa and Oceania) on authorship counts.

Results of the modeling exercise are shown in Tables 2.4 and 2.5. Models have Nagelkerke/Cragg&Uhler pseudo R^2 of >0.5 which represent a reasonable fit. In Model 1,

Congo, Rwanda, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, San Marino, Sao Tome and Principe, Serbia, Slovenia, Solomon Islands, Somalia, Suriname, Swaziland, Syria, Tajikistan, Timor-Leste, Togo, Tonga, Tunisia, Tuvalu, United Arab Emirates, Uzbekistan, Vanuatu, Yemen.

both GDP-PPP and population are highly significant (at the 1% level of significance). However, the coefficients for these variables are very small. When everything else is held constant, a $1 billion increase in GDP-PPP increases the authorship count of a country by 0.05%. Increasing population by a million increases national participation by a very small proportion. Other variables show much stronger positive effects: English-speaking countries, on average, have 2.4 times the levels of authorship of Non-English-speaking countries (1% level); tertiary education level increases of 1% lead to 10% greater participation (1% level); Annex 1 countries on the average have more than 3.5 times as many authors as Non-Annex 1 countries even after controlling for population and national income effects (1% level). On the other hand, a 1 point increase in the 7 point vulnerability index scale *reduces* participation by 22% in the IPCC even after the effects of income and population are controlled for. When Annex 1 countries (Model 2) alone are considered only the level of tertiary education is significantly correlated with IPCC participation, and all other socio-economic variables are no longer significant.

Table 2.4: Model results of the negative binomial regression for IPCC count data *(Model 1 includes all countries; Models 2 and 3 are for Annex 1 and Non-Annex 1 countries, respectively)*

Variable	**Model 1**	**Model 2**	**Model 3**
Constant	0.69	-2.67	1.06
Population	$4.02*10^{-9}$ (***)	$1.9*10^{-8}$	$1.94*10^{-9}$
GDP	0.00055 (***)	$-1.72*10^{-4}$	0.0009(**)
English (dummy)	0.87(***)	-0.42	1.26(***)
Tertiary Education	0.098(***)	0.17(***)	0.097(***)
IPCC Effect	0.41	0.51	0.59
Vulnerability Index	-0.25 (*)	0.61	-0.467(**)
Annex 1 (dummy)	1.29 (**)	-	-
Nagelkerke/Cragg&Uhler pseudo R^2.	0.57	0.6	0.37

(* = 10% level; ** = 5% level; *** = 1% level)

Table 2.5: Model results of the negative binomial regression for IPCC count data to test for regional differences				
Variable	**Model 3a**	**Model 3b**	**Model 3c**	**Model 3d**
Constant	0.062	0.0087	-1.16	0.16
Population	$1.83*10^{-9}$	$3.87*10^{-9}$	$5.35*10^{-10}$	$2.64*10^{-9}$
GDP	0.00075(***)	0.0012(**)	0.0015(**)	0.0007(**)
English (dummy)	1.017(***)	0.8(**)	0.7(**)	0.8(**)
Tertiary Education	0.14(**)	0.135(**)	0.168(***)	0.144(**)
IPCC Effect	0.32	0.35	0.34	0.39
Vulnerability Index	-0.14	-0.08	0.07	-1.64
Oceania	-1.35(**)			
Asia		-0.57(*)		
Africa			0.96(***)	
Latin America				-0.44
Nagelkerke/Cragg&Uhler pseudo R^2	0.56	0.53	0.57	0.52

(* = 10% level; ** = 5% level; *** = 1% level)

Some effects seen in Model 1 persist when only Non-Annex 1 countries are considered (Model 3). GDP-PPP, English-speaking status, levels of tertiary education, and vulnerability all show stronger effects than in Model 1, while population is no longer a significant determinant of participation. In particular, tertiary education levels, English-speaking status, and vulnerability to climate all show strong effects. Among Non-Annex 1 countries, English-speaking status increases the authorship counts by a factor of 2.5 (1% significance), while an average of 1% increase in tertiary education levels increases participation by 10% and a one-point increase in the vulnerability scale *decreases* participation by 40% (at 1% and 5% levels of significance, respectively).

The impact of regions on Non-Annex 1 participation was tested in Models 3a through 3d. In Models 3a, 3b, 3c, 3d, individual dummy variables were used for Oceania, Asia, Africa and South America, respectively. After accounting for the other causes for variation in participation, and *relative* to the other Non-Annex 1 countries, it was found that those in Oceania are under-represented, while those in Africa have greater representation. There are more than three times as many African authors and 75% fewer authors from Oceania than would be expected from their levels of socio-economic activity and other variables. GDP, English-speaking status and tertiary education levels are all positively and significantly correlated with authorship in the IPCC across all model specifications.

2.6 Conclusions and broader implications of IPCC authorship

If we accept the premise that participation in a major synthesis endeavour such as the IPCC is indicative of a country's ability to generate knowledge that is relevant for the climate problem, then what do the summary statistics and the generalized linear regression models tell us about the more general problem of scientific capacity to address climate change? The data show that involvement of Non-Annex 1 (developing) countries in the IPCC continues to lag behind that of developed countries. Nearly half of all countries have never participated in the authorship of any of the four reports and all of them are Non-Annex 1. The model results in Table 2.4, show that Annex 1 countries have more than 3.5 times as many authors as Non-Annex 1 countries even when accounting for education, population, socio-economics, and language. Many of these variables change only slowly with time; so any further increases are likely to be slow.

Regional differences in participation are also apparent from both summary statistics, as well results of the regression analysis. In particular, countries of Oceania and Asia lag behind the rest of the world even after accounting size of their population and economies. These regional differences also mask internal inequities within the region. Only a small number of countries contribute to the regional totals for the Non-Annex 1 countries, while most Annex 1 countries contribute to their regional totals. A striking finding of this work is the extent to which a nation's English- speaking status influences participation among Non-Annex 1 countries. Controlling for other factors, participation by authors from English-speaking Non-Annex 1 countries is 2.5 times greater than those Non-Annex 1 countries that are non-English speaking. English is the global language of science, and climate science and assessment is no exception; differing abilities to use English may be influencing participation in global climate change assessments.

The findings indicate that participation in climate change assessment is not commensurate with what countries stand to lose. For instance, oceanic countries and small island nations such as Tuvalu, Kiribati, Vanuatu, Fiji and others are only several meters in altitude and are the most vulnerable to destruction from increasing storm surges along coasts. They will likely be the first to evacuate with anticipated global sea level rises. Unfortunately, they are very poorly represented and often entirely absent from any participation in the IPCC assessment. Fiji is the only low-lying small island nation to contribute to any of the IPCC reports. Even at that, the country had only two contributing authors across all four IPCC reports spanning 17 years.

At a broader level, what explains the lack of participation by developing countries in the IPPC? The reasons are manifold but fall broadly into two categories. The first set of explanations relate to the process by which the IPCC includes developing country participants. The second relate to the scientific capacity (or lack thereof) of the many countries of the developing world.

IPCC efforts to increase developing country participation began with the Second Assessment Report in 1995, which put climate change squarely on the international agenda. Procedures (such as the lead author requirement) were put in place that required the IPCC to improve representation. While the IPCC has made limited progress in developing country authorship for LAs and CLAs, much work remains to be done in increasing lead author representation. Further, the difference in the numbers of contributing authors (CAs) between less and more industrialized counties is stark. This is largely a result of the routine functioning of science and scientific networks. CAs are invited on an as-needed basis; LAs and CLAs responsible for a chapter are more likely to call upon experts they are familiar with. All things being equal, scientists in the developing world are less likely to be 'plugged-in' to global networks and may have a lower publishing profile than their Annex 1 counterparts; this likely contributes to their under-representation as CAs. Although there are creditable efforts in increasing developing country LA and CLA participation through formal channels, the lack of Non-Annex 1 CAs suggests that there is room for improvement in the ways in which the IPCC informally integrates scientific expertise into the assessment process. The advantage English speakers have might also be a result of such informal networks.

These efforts notwithstanding, developing country participation in the IPCC remains low. As we discuss in a related work (Kandlikar et al., 2011) the capacity to engage in climate science and related global assessments in much of the developing world is poor. Ability to generate relevant knowledge about climate change is often lacking in the developing world due to resource constraints that result in an absence of adequate human capital, data limitations, and weak infrastructure. The results of our analysis in Tables 2.4 and 2.5 confirm this; among Non-Annex 1 countries those that have greater DP and levels of tertiary education show greater participation. Among Annex-1 countries, while income indicators are not significant, levels of tertiary education have a high coefficient and are highly significant, indicating that levels of investment in higher education are important. Paradoxically, the most vulnerable countries are less likely to participate in the IPCC. Within countries the translation of the science that is generated (either globally or locally) into policy relevant information is often limited by level of demand for such information by relevant decision-makers, and a lack of demand for climate research reinforces the relative absence of expertise. In the absence of institutions that can act on weather and climate related information, the relevance of scientific capacity is diminished, and vice versa. While hard to capture in a quantitative manner, these interacting factors limit the extent of developing country capacity in climate science, and this has a knock-on effect on their ability to participate in the IPCC.

In addition to the level of participation, the type of participation is also relevant. A little over half of the Non-Annex 1 authors belong to Working Group II, which focuses on Impacts and Adaptation. The rest are fairly evenly split between WG I and WG III. There are likely two reasons for this is so: First, the presence of regional chapters in WGII vastly increases the chance that a developing country participant is included in WGII. Indeed, the representation from many countries is almost solely through these regional chapters. Second, Non-Annex 1 countries tend to prioritize science that is relevant to more local scale climate issues and the burdens that may come with adapting to climate and weather variation rather than either the underlying global science questions or the need to reduce emissions. Some of this capacity exists in national institutions aimed at weather forecasting and use; thus a priority on impacts and adaptation addresses the pressing needs of Non-Annex 1 countries and more efficiently uses the limited capacity and resources available.

While we have low levels of participation by developing countries in the IPCC why should we be concerned about low levels of participation in the IPCC? Should IPCC make renewed efforts to increase participation, but also find ways to increase capacity for climate assessment in the developing world? The most obvious reason is the political legitimacy of the entire enterprise. This paper does find that IPCC's procedural rules born out of instrumentalist concerns have improved participation. While imperfect the 'quota' system for chapter lead authors instituted in the late 1990s has led to a small rise in developing country participation.

However, the IPCC is more than just another UN bureaucracy that needs to 'add up the participation numbers'; there are substantive reasons for increasing participation. The IPCC is a scientific body whose work is under intense scrutiny. The absence of developing country expertise can also impact the quality of the resulting product. The Himalayan glacier fiasco in AR-4 demonstrated (Pearce, 2010) that the actual inclusion of regional experts might be needed to improve quality. As the late climatologist Stephen Schneider noted "[T]here are only a few authors in each region, so it narrows the base of science" (quoted in Pearce, 2010). Our data also shows that non-Annex 1 scientists are under- represented in both climate science questions and on mitigation (the focus of WGI and WGIII respectively). As climate negotiations move to consider limits on Non-Annex 1 emissions, those who can understand particular questions surrounding technology development, adoption and diffusion in home countries will be needed.[7] Similarly, as the global community moves (as was agreed in Copenhagen) to spend tens of billions of dollars helping the developing world adapt to climate change, the IPCC will need to incorporate appropriate forms of local knowledge into its work (Jasanoff and Martello, 2004). This will certainly be a real challenge for the IPCC; as Hulme (2010) notes ''it is easy for global institutions of knowledge-making to become insensitive to a geographical sensibility''.

Finally, there are normative and ethical reasons for why low levels of developing country participation in the IPCC are a concern. The climate change policies will cost billions of dollars with big differences in outcomes for winners and losers. National economic interests have shaped climate negotiations from the very outset and will continue to do so. As an international body with a global mandate the IPCC should do better than to reproduce the existing relations of power; it should strive towards better representation of the interests of those who will face the brunt of the problem. Increasing the capacity of developing countries to participate in its assessments will be a step in the right direction.

[7] This was arguably an acceptable situation in the past. For example, the development of global climate models and participation in the synthesis of their results might not have been the most effective use of time for Non-Annex 1 scientists given the need to engage in locally relevant climate science related to impacts and adaptation. Similarly, mitigation has been seen by many (including some Non-Annex 1 countries) as a problem for the industrialized world to solve. However valid these arguments might have been, it is not clear that future IPCC assessment reports will be well-served by such a split.

3. Building Scientific Capacity to Address Climate Change in the Developing World: Is There a Case for Coordination?

3.1 Introduction

While developing countries are more vulnerable to the most serious effects of climate change than developed countries, they do not have the same capacity to cope with such challenges. A recent quantitative study has demonstrated that scientists from developing countries are nowhere near proportionately represented in global climate science initiatives like the United Nations Intergovernmental Panel on Climate Change (IPCC), even after a range of factors such as GDP and population are accounted for (Ho Lem et al., 2011). Indeed, an internal assessment conducted by the IPCC confirms that while the proportion of developing country scientists participating in the IPCC improved from the Second Assessment Report (SAR) in 1995 to the Third Assessment Report (TAR) in 2001, there was not an increase in such participation between the TAR and AR4 (2007). In other words, there has been a "stagnation" of developing country scientist participation that "justifies that measures be taken to improve their participation" (IPCC, 2009b).[8]

Capacity building to address climate change is one promising avenue to begin to marshal the necessary human capital in developing countries that is required to tackle this complex global issue and begin to address the disparity noted between developed and developing countries. While there is a wealth of literature on the topic of scientific capacity (see Sections 1.1 and 1.2, above), for the purposes of this thesis scientific capacity is understood as: (1) the effective production and synthesis of knowledge, and (2) the effective use of climate knowledge enabled by mechanisms for knowledge translation and feedback (Kandlikar et al., 2011). This systemic approach to capacity building is particularly suited to the global climate change issue and recognizes that building capacity is an ongoing and dynamic process.

[8] The IPPC assessment recognized that because authors can only be linked to their country of institution, it would tend to underestimate the number of developing country authors and reviewers. This consideration was insufficient to lessen the concern of under-representation of such scientists. It also confirms a lack of scientific institutions participating in the IPCC assessment reports.

The international community has identified building capacity in developing countries to address climate change as a priority. In 2001, at the Seventh Conference of the Parties (COP 7) in 2001, “The Marrakesh Accords” included Decision 2 on Capacity Building in Developing Countries (Non-Annex I Parties). This decision has been reaffirmed by subsequent COP gatherings as having ongoing relevance and importance. Notably, this decision under the United Nations Framework Convention on Climate Change (UNFCCC) states:

> “…capacity building for developing countries is essential . . . There is no ‘one size fits all’ formula for capacity building. Capacity building must be country-driven, addressing the specific needs and conditions of developing countries and reflecting their national sustainable development strategies, priorities and initiatives… Capacity building is a continuous, progressive and iterative process, the implementation of which should be based on the priorities of developing countries… Capacity-building activities should be undertaken in an effective, efficient, integrated and programmatic manner, taking into consideration the specific national circumstances of developing countries.”

In terms of specific priorities, COP 7 articulated a fifteen-point framework for capacity building in developing countries to address climate change that included:

- (i) institutional capacity-building
- (ii) enhancement and/or creation of an enabling environment
- (iii) national communications
- (iv) national climate change programmes
- (v) greenhouse gas inventories
- (vi) vulnerability and adaptation assessment
- (vii) implementation of adaptation measures
- (viii) assessment for implementation of mitigation options
- (ix) research and systematic observation
- (x) development and transfer of technology
- (xi) improved decision-making

(xii) clean development mechanism

(xiii) needs arising out of the implementation of Article 4, paragraphs 8 and 9, of the UNFCCC (i.e. funding, insurance, and transfer of technology)

(xiv) education, training and public awareness

(xv) information and networking

While the need to build capacity in developing countries to address climate change has been recognized by the international community for some time, and various commitments have been made to advance capacity building in these countries that are the most vulnerable, there is no published literature that comprehensively seeks to identify and analyze the various strategies and activities that have been launched to address this pressing concern.

This paper uses interviews with key informants along with an extensive review of open source qualitative data to describe, analyze, and evaluate the state of scientific capacity building activities of leading climate change organizations for developing country scientists. Specifically, the following research questions are addressed:

1) How have international institutions shaped the development of national scientific capacity in the developing world to address climate change?
2) What are the challenges, gaps, and drawbacks of these capacity building activities?
3) Should a coordinated response to building scientific capacity to address climate change be pursued? If so, how?

3.2 Methodology

The study began with an extensive open source research exercise to identify the leading organizations that were active in building scientific capacity in developing countries to address climate change. With this high-level information, programs and individuals who could be potential interview subjects were identified for semi-structured in-depth interviews. These expert interviews provided further information on programs and strategies related to scientific capacity, but also key insights into the gaps, drawbacks, and challenges of such activities. Many of the interviewees also provided previously unpublished documentation related to this topic that proved invaluable. The open source and interview data were then considered together to identify major findings as described below in greater detail.

3.2.1 Open source

Background research was conducted to identify the key institutions delivering scientific capacity building programs and the specific programs involved. Once these institutions were identified through key word searches, a closer look at their capacity building programs was undertaken. Criteria was developed to discern which programs would be included, based upon whether or not the programs involved strategic capacity building around climate science and if they were targeting developing country scientists.

Basic information was first collected to provide an overview on the main institutions involved including: relevant program name(s); categories of program activities and areas of focus; the main goals of the program(s); and contact information of key project personnel. For each program, information was then systematically collected in a database, including information regarding:

1. Name, description and objectives of program (elements of the climate change problem that are addressed by the program)
2. Program details (type of program, how it operates, implementation, source of funding, etc.)
3. Nature of activities and areas of focus
4. Summary of main achievements
5. Statistics on beneficiaries (how many and who they are)
6. How beneficiaries are selected

This information was primarily gathered from open-source documents available on the Internet with the majority of information collected in the fall of 2010. This information was then updated after completion of the interviews mentioned below, current to February 2012. Once the database was completed, the names and summaries of each program were organized according to the five main strategic approaches identified in Section 3.2 of this paper. This open source database information was then combined with the interview results described below, and integrated into two summary tables (Figures 1.1 and 1.2 appearing later in this document). Specific information on each program was then examined in a comparative manner (see Section 3.3 of this paper).

3.2.2 Interviews

In-depth, semi-structured interviews (Wengraf, 2001; Cohen, 2006) were conducted with sixteen key informants who were senior representatives of leading intergovernmental, governmental, and non-governmental scientific organizations that are focused on addressing climate change on an international or regional scale. These anonymous, expert interviews were conducted by telephone between September 15, 2010 and January 25, 2011, with the exception of two subjects being interviewed in person on April 2nd, 2010 in Japan. The interviews were undertaken in accordance with procedures and protocols approved by the UBC Behavioural Research Ethics Board.[9] Each of the interviewees gave their consent to the interviews being audio-recorded. The average duration of each interview was between sixty and ninety minutes, with many interviewees providing additional documentation after the completion of their interview to facilitate the exchange of information about their organization and its capacity building activities.

Interview subjects were initially identified by the extensive open source investigation through their linkages with organizations that are active on the issue of climate change science. Representatives of these organizations were invited to participate in the study. Additionally, a "snowballing" technique was employed, such that interviewees were asked to identify other potential interviewees. This method was employed until the expanding interviewee pool eventually ceased to generate new potential interviewees, projects and organizations, demonstrating with a reasonable degree of confidence that the appropriate key informants had been fully identified. The response rate was very good, with 71% of organizations (12/17) agreeing to participate of those invited. Interview

[9] UBC Behavioural Research Ethics Board, Certificate of Approval # H08-01857, issued November 3rd, 2008 (renewed)

subjects represented a diverse array of organizations with broad geographic distribution, including in Belgium, Brazil, Canada, Egypt, Germany, Japan, Switzerland, and across the United States.

Once the interviews were completed, transcripts were prepared of each interview. Due to the number of interviews, it was not necessary to have recourse to computerized coding software. Instead, the interview transcripts were manually coded using key projects as well as major themes that were apparent from a review of the transcripts in their entirety and the interview protocol that was utilized. As with the information collected in the database, any program specific data was ordered according to implementing organization and analyzed via the five main strategic approaches identified in Section 3.2 of this paper. The major themes identified were then used to re-organize the remaining interview data to facilitate comparative analysis and the identification of qualitative research findings.

3.3 Results and discussion

The first issue examined in this study is the rationale for building scientific capacity – an issue of some importance since it both drives the capacity building agenda of the various organizations involved, and provides a set of objectives to assess the efforts being undertaken. The specific capacity building activities are then described and analyzed according to five major typologies: graduate scholarships and post-doctoral fellowships, trainings and workshops, research collaboration, organizational support, and regional and global networks. Thereafter, the issue of capacity building at the IPCC, the premier global scientific organization that addresses climate change, is reviewed. Finally, the gaps, drawbacks, and limitations of capacity building for climate change are examined, including: institutional barriers, financial issues, the "brain drain" phenomenon, data access and quality, technology and research resource limitations, difficulties with downscaling/up-scaling of climate modeling, the interdisciplinary nature of climate change, navigating the science-policy interface, and issues related to operating across culture, language, and gender. Unless otherwise indicated, quoted material below is from the interview data described above and is presented anonymously.

3.3.1 Rationale for building scientific capacity

Interviewees were unanimous in recognizing the need to build scientific capacity to address climate change. Many considered the reasons to be self-evident, and even intrinsic in the work of their organizations. A synthesis of the interview data reveals that climate change is a complex global issue that can only be addressed on a sustained basis through interdisciplinary and distributed capacity that involves collaboration between developed and developing countries alike. As one interviewee explained: "[building capacity] takes sustained investment over long periods of time. Anyone who thinks you can go in and run a few trainings and change the outcome for a community or decision environment is very hopeful in their thinking." The climate change problem is so vast and multifaceted that the total number of scientists working currently on climate change may be insufficient. One interviewee noted: "the [IPCC climate change] program is so encompassing that the number of scientists overall who are working on these issues is not enough."

Many interviewees highlighted the importance of building capacity specifically of developing country scientists because their contributions will improve global, regional, national, and local responses to climate change both now and for "future generations". As one interviewee stated: "you need scientific communities in the developing world to be full participants to be contributors to the science, participating in international assessments like the IPCC, be aware of research being done and how to integrate that information." Building scientific capacity in the developing world was also believed to be necessary for there to be "distributed capacity" around the world in "order to have locally tailored responses" to climate change, and to provide a "link" between decision-makers and climate information. One interviewee explained: "Building capacity regionally in the developing world is fundamental for countries to understand the amplitude, intensity, impact, vulnerability and also to make them understand the importance of global responses to climate change to reduce future risks, to mitigate, and reduce emissions into the atmosphere." Another interviewee echoed this, saying: "We find a lot of developing countries have no knowledge of how to develop adaptation strategies because they don't have the skills to conduct vulnerability assessments." The role of capacity building in local knowledge production, use, translation, and feedback (Kandlikar et al., 2011) was described by several interviewees.

Enhanced scientific capacity within developing countries was also perceived as necessary to overcome a tendency of developing country governments to simply ignore the climate change problem. As one interviewee expressed: “Scientific capacity makes a key difference between inaction and concerted action.” Only a few interviewees explicitly raised concerns about the particular vulnerability of developing countries to climate change as a need to build scientific capacity in those countries. When interviewees did discuss those countries most at risk, Africa was highlighted as “the continent most vulnerable to climate change because it lacks the resilience and adaptive capacity.” None of the interviewees raised ethical arguments that developing countries should be given assistance to build scientific capacity to address climate change given that these countries are expected to bear the brunt of climate change impacts, despite the much greater contribution of developed countries to the climate change problem. However, one interviewee did reference Article 10 of the *Kyoto Protocol to the United Nations Framework Convention on Climate Change* which obliges Parties to cooperate in, and support, capacity scientific building, especially in developing countries.

3.3.2 Programs and strategies

Capacity building programs specifically directed towards developing country scientists to address climate change that are supported, or administered, by the following international organizations were examined in this study:

1. Intergovernmental Panel on Climate Change (IPCC)
2. United Nations Framework Convention on Climate Change (UNFCCC)
3. International Research Institute for Climate and Society (IRI)
4. global change SysTem for Analysis, Research and Training (START)
5. International Human Dimensions Programme on Global Environmental Change (IHDP)
6. Institute for Global Environmental Strategies (IGES)

7. World Metrological Organization – World Climate Research Program (WMO – WCRP)
8. United Nations Environment Programme (UNEP)
9. International Development Research Centre (IDRC)
10. United Kingdom Department for Foreign and International Development (DFID)
11. U.S. Agency for International Development (USAID)
12. Asia Pacific Network for Global Change Research (APN)
13. Inter-American Institute for Global Climate Research (IAI)
14. International Geosphere-Biosphere Programme (IGBP)
15. Stockholm Environmental Institute (SEI)
16. The Academy of Sciences for the Developing World (TWAS)
17. United Nations Institute for Training and Research (UNITAR)

Table 3.1 (below) identifies the various types of capacity building programs that were identified and included in this study, listed by organization. While extensive, this listing is not intended to be exhaustive but instead focuses on the major programs of these organizations that are relevant to this study.

Table 3.1 Capacity building programs for climate change by organization considered in study

	Graduate Scholarships & Fellowships	Trainings and Workshops	Collaborative Research	Organizational Support	Networks
IPCC	IPPC Scholarship Programme	IPCC Workshops for Participating Authors	IPCC Assessment Reports		IPCC (1988 to present)
UNFCCC	UNFCCC Fellowship Programme				
IRI		IRI Training Program and Online Learning Modules, including the Climate Predictability Tool			
START	START African Doctoral Fellowship program (2002-2006) African Climate Change	START Advanced Institutes Program	Fellowships and Visiting Scientists (1995-2006) Assessments of Impacts and Adaptations to Climate Change (AIACC) (2002-2007)		START (1992 to present)

Table 3.1 Capacity building programs for climate change by organization considered in study

	Graduate Scholarships & Fellowships	Trainings and Workshops	Collaborative Research	Organizational Support	Networks
	Fellowship Program (ACCFP) (2007-2011)		Africa Small Grants (2003-2009) Advancing Capacity to Support Climate Change Adaptation (ACCCA) (ended in 2010)		
IHDP		IHDP International Human Dimensions Workshops (IHDW) (1998 to present)			IHDP (1990 to present)
IGES				National Law & Policies; Human Resource Development in Higher Education; Assessment of Education for Sustainable Development Programmes	IGES (1998 to present)
WMO – WCRP		Training workshops in collaboration with START, including funding early career scientists to attend capacity building activities			
UNEP			Assessments of Impacts and Adaptations to Climate Change (AIACC) (2002-2007)		A series of global and regional networks related to enhancing capacity to share climate data and information between countries
IDRC	African Climate Change Fellowship Program (ACCFP) (2007-2011)	Climate Change Adaptation in Africa (CCAA) Training Workshops	Assessments of Impacts and Adaptations to Climate Change (AIACC) (2002-2007) Advancing Capacity to Support Climate Change Adaptation pilot projects (ACCCA) (ended in 2010)	African Adaptation Research Centres (AARC) (2011-2014)	CCAA Learning Forums and AfricaAdapt
DFID	African Climate Change Fellowship Program (ACCFP) (2007-2011)	CCAA Training Workshops	Advancing Capacity to Support Climate Change Adaptation pilot projects (ACCCA) (ended in 2010)		CCAA Learning Forums and AfricaAdapt
USAID		USAID Global	Assessments of Impacts		

Table 3.1 Capacity building programs for climate change by organization considered in study					
	Graduate Scholarships & Fellowships	**Trainings and Workshops**	**Collaborative Research**	**Organizational Support**	**Networks**
		Climate Change Program (GCCP)	and Adaptations to Climate Change (AIACC) (2002-2007)		
APN		APN Workshops	Annual Regional Call for Proposals (ARCP); Scientific Capacity Building/Enhancement for Sustainable Development in Developing Countries (CAPaBLE) (2003 to present)		APN (1990 to present)
IAI	IAI Fellowship Program (last ten years)	IAI Training Institutes (1999 to present)	IAI Collaborative Research Networks Program (Phase I: 1999-2006; Phase II: 2006-2011)		IAI (1992 to present)
IGBP		IGBP Training Workshops and Summer Schools	IGBP Core-projects involve capacity building components		IGBP (1988 to present); START originated by IGBP; IGDP Post-Doctoral Networks
Stockholm Environmental Institute			Advancing Capacity to Support Climate Change Adaptation (ACCCA) (ended in 2010)		
TWAS	TWAS Prizes for developing country scientists		Assessments of Impacts and Adaptations to Climate Change (AIACC) (2002-2007)		
UNITAR		Capacity Development for Adaptation to Climate Change & GHG Mitigation in Non-Annex I Countries (C3D+) (2003 to date)	Advancing Capacity to Support Climate Change Adaptation (ACCCA) (ended in 2010)	Capacity Development for Adaptation to Climate Change & GHG Mitigation in Non-Annex I Countries (C3D+) (2003 to date)	

Table 3.2 (below) provides aggregate qualitative data on overall metrics related to each of these capacity building programs, including scientific domain, geographic scope, participant information, funding, duration, and scale. It is notable that the scale of the projects increases both in terms of funding, duration, and scale as one proceeds from graduate scholarships and fellowships up to networks.

Table 3.2 Scope of capacity building programs considered in study

	Graduate Scholarships & Fellowships	Trainings and Workshops	Collaborative research	Organizational support	Networks
Scientific domain	Climate science; Global Environmental Change	Climate science; modeling; climate forecasting; data management; statistical analysis; downscaling; Global Environmental Change; Developing country vulnerabilities and adaptation options; Climate Variability; Asian Monsoons; Climate adaptation in Africa; Climate risk assessment; Proposal writing	Diverse range of topics related to climate change and climate science; vulnerabilities and adaptations; generate and communicate information useful for adaptation planning and action	Climate change adaptation and mitigation action; environmental and sustainability education	Diverse range of topics related to climate science, climate change, data; sharing and synthesis of knowledge on vulnerabilities, adaptation,
Geographic scope	Africa; Least Developed Countries; Small Island Developing States; the Americas	In-person (in developing and developing countries around the world) and online; some organizations have a Continental focus	Africa, Asia Pacific, Americas, Small Island States	Africa, Asia-Pacific, and selected countries: Senegal, South Africa, Laos, Thailand, Sri Lanka, China and Samoa; Benin, Ghana, Egypt, Tanzania, Burkina Faso, South Africa, and Kenya	Africa (AfricaAdapt; AfricaNESS, CCAA Learning Forums), Asia Pacific (APN, IGES), Americas (IAI), global (IPCC, START, IHDP, IGBP); in-person and online
Participants	Undergraduate, Masters, Ph.D and Post-Doctoral students	Professionals, technicians and scientists in developing countries	Senior scientists, researchers, early career scientists, graduate students	National and global centres of excellence; universities	Typically scientists / researchers who are participants in other capacity building initiatives (i.e. scholarship / fellowship recipients, or collaborative research grantees); networking also directed at national focal points
Funding	US$5000 to US$25,000 per year	Varies widely (e.g. $80,000 for a 2 week workshop)	$15,000 to $1 Million per grant	$1-$1.5 million per institution (average)	Varies widely; one to several million dollars per regional network
Duration	1-3 years	2 days – 6 weeks	1 – 7 years	3 years and ongoing projects	Decades
Scale	10-45 per year (per program)	10-50 participants per session	170-235 participants per organization	Multiple organizations	17 individuals to 177 countries

Each of the projects described in Table 1.1 are explored below and compared with one other in Section 3.3.2.1 to 3.3.2.5. Four major integrated capacity building initiatives that cut across various capacity building activities and strategies, however, are briefly introduced here before the various individual approaches to capacity building for developing country scientists addressing climate change are explored.

First, the Advancing Capacity to Support Climate Change Adaptation (ACCCA) project was a collaborative effort between UNITAR, START, SEI, Environnement et Développement du Tiers Monde (ENDA-TM), and Climate System Analysis Group (CSAG-UCT), ending in July 2010. The ACCCA involve nineteen pilot projects in developing countries around the world (i.e. Nigeria, Ghana, Mali, Niger, Tunisia, Malawi, Kenya, Tanzania, Ghana, Nepal, Mongolia, India, Philippines, Bangladesh, Burkina Faso, Cameroon, Ethiopia, Kenya, and South Africa). The focus of the projects was on "building capacity, engaging civil society, and implementing pilot actions related to the UNFCCC and other multilateral environmental agreements" (ACCCA, 2012). Interestingly, some of the project funding for these ACCCA projects came from the CCAA project, which in turn is funded by IDRC/DFID. This highlights the inter-related nature of these initiatives.

Second, the Assessments of Impacts and Adaptations to Climate Change (AIACC) initiative was implemented by the UNEP and delivered by START and TWAS. The AIACC (2002-2007) was developed in collaboration with the IPCC, and funded through the Global Environment Facility (GEF), USAID, IDRC, the United States Environmental Protection Agency, and the World Bank. This global program funded collaborative scientific research on climate change to build capacity of developing countries "to assess climate change vulnerabilities and adaptations, and generate and communicate information useful for adaptation planning and action" (AIACC, 2012). The AIACC model is unique for its "adaptive management" style, which allowed for a more flexible and dynamic approach to capacity building that was driven by participants themselves. One interviewee described the approach taken by START in implementing the project:

> "The [AIACC] program was effective because it involved teams of scientists, various subject area experts, some policy makers, within 24 different nations or regions that were focused on a task: to put together an assessment of climate change adaptation and vulnerability options. Having them not in separate individual projects, but teams interacting with each other. We had workshops to bring these teams together, fellowship programs. One thing that was very positive is that some of these teams developed their own training options programs and workshops in which they invited members of other teams from other nations to participate in capacity building efforts. We had multiple institutions working together and opportunities for them to get together with their peers, working on similar problems in other parts of the world. Another aspect was that it was a very soft management style in which each team had a great deal of responsibility and latitude to set their goals, what projects they would do, what scenarios, what analytic methods – none of it was dictated from the START office. This allowed for changes to projects and change course when they found something made more sense to do."

Third, the Climate Change Adaptation in Africa (CCAA) project (funded by IDRC and DFID) has developed into a comprehensive approach to building capacity of developing country scientists in Africa over an extended period of time. The inter-related activities were described by an interviewee as follows: "These [45 projects across the continent] obviously have a brilliant diversity not just in subject matter, but also in terms of expertise and experience, and the capacities of the individual research teams … So what we did was launch a series of capacity building workshops, … we would have consultants organize a conference or a workshop, bring the guys together, and then provide follow-up visits and promote exchanges between projects to build up capacity. And then the final stage has been the learning forums as they are coming to the end of their research and are now exchanging knowledge, results, lessons learned and so forth. So it has been a multi-phased program of capacity building." The CCAA project strategically also has a very high level of local participation: "All of our research partners are African scientists, with very few exceptions. The vast, vast majority of our partners, and all of our projects are led by African institutions. More than 95% of the people involved in our programs are African. In terms of the training workshops, again any workshop is delivered by an African trainer from African Universities. In one or two cases, as with the learning forums, we had individuals from abroad. But once we established a methodology that worked, we're getting an African to do it. It is an integral part of our approach".

Finally, the Advanced Institutes program run by START is one of the most sophisticated capacity building programs for early career scientists from developing countries identified in this study. Twenty fellows per year from throughout the developing world participated in Advanced Institutes on a wide range of themes related to climate change. The Advanced Institutes program involves "(1) an intensive training workshop at an international center of excellence; (2) follow-on research grants that provide an opportunity for fellows to apply knowledge and tools learned during the training workshop; and (3) a synthesis workshop to exchange results and experiences. All fellows receiving research grants are assigned mentors who serve as a resource, provide oversight to ensure the project stays on track, help expand the researchers' network, and serve as advocates of the researchers in their home institutions." (START, 2012e)

3.3.2.1 Graduate scholarships and post-doctoral fellowships

The first and most basic capacity building program identified in this study was support for aspiring scientists in developing countries to receive funding to obtain graduate-level education (M.Sc., Ph.D.) and pursue post-doctoral research specifically related to climate change. For these programs, scholarships provided funding of between US$5000-25,000 per year for between one to three years to cover some combination of living expenses, tuition, and research materials, often at universities in the developed world.

Organizations engaged in this form of capacity building and their programs include the IPCC Scholarship Programme, START African Doctoral Fellowship program, the Climate Change Adaptation in Africa (CCAA) project (IDRC-DFID), and the IAI

Fellowship program. The most high profile of these programs is the IPCC graduate scholarship program that was funded from the interest from the IPCC's Nobel Peace Prize award. An interviewee describes the genesis and scope of this initiative as follows:

> "…it was decided to fund … scholarships to help least developed countries and Small Island State scientists to study at the PhD or Masters level for up to three years through a limited number of grants, and we hope to announce soon the first ten grants to be given to ten scientists. Compared to the size of the problem, ten grants is a small contribution. It is quite remarkable that the call for proposals for that program we were overwhelmed when we received 2,000 applications for this scholarship program that shows the size of this area and we can only fund 10. Those 2,000 applications means that 1,990 others will be left unsatisfied… The scholarship grants are $20,000 per year, or something like that, to a maximum, it is meant to cover an estimate of living expenses, studying expenses but not tuition fees."

Indeed, a total of nine young students and researchers from developing countries, including three women, were awarded a scholarship for postgraduate studies or research for the period 2011-2012, with the IPCC hoping to maintain the scholarship program on an annual basis (IPCC, 2012c). The demand for programs that support graduate-level education in climate sciences in the developing world is massive.

In a potential move to minimize the "brain drain" phenomenon, the START African Doctoral Fellowship program (2002-2006) took a unique approach of funding doctoral-level study of young African scientists at African universities. One interviewee described the rationale for such programs is "to build a community for the long term" to address climate change. This extensive program was the forerunner for the African Climate Change Fellowship Program (ACCFP), a more recent program administered by START, together with the Institute of Resource Assessment (IRA) of the University of Dar es Salaam and the African Academy of Sciences (AAS). Funding for the ACCFP initiative came from the CCAA (IDRC-DFID). Phase I of the program ran from August 1, 2007 to December 31, 2010, and Phase II funding was then approved by the CCAA. The fellowships included a range of individuals, primarily early in their careers, including Policy Fellowships, Teaching Fellowships, Doctoral Research Fellowship, and Post-Doctoral Fellowships. Fellows were supported to visit and collaborate with numerous institutions on research projects related to climate risk, vulnerability, adaptation, and/or bridging the science-policy divides. Learning seminars also allow fellows, their host supervisors and policy communities to share experience and further debate on climate change in Africa. Linkages between Home and Host Institutions were facilitated through this inter-African fellowship program. Workshops also supported fellows in developing their skills and experience related to particular aspects of climate change.

The ACCFP's ambitious objectives related to building capacity in Africa to address climate change were to:

(i) contribute to institutional strengthening by building human resource capacity in participating institutions;

(ii) develop a sustainable collaborative network of institutions that can provide learning opportunities for young scientists and professionals; and

(iii) train a cadre of young scientists and professionals to advance understanding of climate change and risks and vulnerabilities, improve management of climate risks and advance adaption, inform policy and decision making, and mainstream climate change education (START, 2012a).

The ACCFP program has a significant vision for the future. At the conclusion of Phase I, START estimated that an additional 1,000 scientists in Africa could be trained and engaged over the next decade through an expansion of the ACCFP to provide the "critical mass necessary to effectively engage African governments and communities in dynamic actions to cope with challenges of changing climate and sustaining ecosystem goods and services essential for sustainable and resilient development." (START, 2012a)

The IAI fellowship program not only provides funding for academic studies of undergraduate, graduate and post-doctoral students, but also provides award recipients with “exposure to scientific environments and from opportunities to link their degree studies with current research activities (through field trips, laboratory experiments, related studies in countries other than their own, and the exchange of scientific data and knowledge with other investigators within the IAI network” (IAI, 2012a).

In addition to these graduate scholarship programs that are specific to climate change, a number of general global graduate scholarship and post-doctoral fellowship programs were reviewed that have supporting developing country climate scientists, including the World Bank’s Robert S. McNamara Fellowships Program and the Joint Japan/World Bank Graduate Scholarship Program, IDRC’s Centre Training and Awards Program (CTAP), the International Institute for Applied Systems Analysis (IIASA) Post-Doctoral Program and Young Scientist Summer Program (YSSP), and the TWAS Prizes for developing country scientists. There are also programs like the UNFCCC Fellowship Programme that supports mid-career professionals to conduct research projects in the Secretariat.

3.3.2.2 Trainings and workshops

The use of trainings and workshops for developing country climate scientists is an extensively used strategy to build capacity in targeted subject-matter areas related to both knowledge and skill acquisition to address climate change. The START Advanced Institutes Program, IRI Training Program and Training Institutes, IHDP International Human Dimensions Workshops (IHDW), IAI Training Institutes, IGBP Training Workshops and Summer Schools, CCAA Training Workshops (IDRC-DFID), USAID Global Climate Change Program (GCCP), and APN workshops have involved trainings and workshops for building capacity of developing country scientists. While some of these programs were global in nature, others focused on specific continents (e.g. CCAA in Africa, APN in Asia). Many of these programs are well known and well regarded, including the several notable examples below:

- *START Advanced Institutes Program*: A training program for young scientists engaging them in cross-disciplinary research and networks of researchers. Trainings held every one or two years for up to 20 fellows on topics including climate variability, global carbon cycles, vulnerability assessments and the Asian monsoon.
- *IRI Training Program* (1997-2002): a series of specialist-training sessions for technicians and experts in developing countries on topics including climate variability, regional climate forecast methodology, and application of climate forecasting to agriculture and policy.

- *IAI Training Institutes* (1998 to present): the IAI runs annual summer "training institutes" as a capacity building strategy to assist professionals from countries throughout the Americas. They typically last between one to two weeks. From 1998 to 2002, these institutes were held exclusively in the United States. However, since 2003, it is notable that all of these IAI Training Institutes have been held in developing countries and emerging economies in the Americas (most recently to least recently in Uruguay, Paraguay, Argentina, Chile, Costa Rica, Brazil, Panama, Jamaica, Mexico, and the Dominican Republic). In addition to these Training Institutes, the IAI also provides scientific and technical workshops and seminars. Hundreds of individuals have participated in the IAI's training and education activities related to climate change (IAI, 2012a).
- *Climate Change Adaptation in Africa (CCAA) Training Workshops*: Beginning in 2007, participants from existing CCAA projects across Africa were involved in up to six workshops hosted annually across Africa. In the past, each workshop has had 30-45 participants and topics have included: integrated climate risk assessment, project management, proposal development, research to policy linkages, gender analysis and mainstreaming, participatory action research, and monitoring and evaluation. African scientists from African universities usually instruct the workshops.

- IHDP's biennial *International Human Dimensions Workshops* (IHDW) has engaged over 200 scientists since 1998. The topics for such trainings and workshops range from high-level scientific issues to specific technical skills and applications.

Capacity building initiatives involving trainings, intensive courses, and workshops for developing country scientists vary widely in duration and depth of coverage of materials. They can be a day or two to up to six weeks in duration. While most trainings and workshops are for small groups of scientists (between 10-20 per session), IHDP's IHDW involves up to 40 early career scientists from developing countries. While participation in a training program may be helpful, interviewees recognized that more is needed to meaningfully building individual capacity than one-off participation: "Being through a training once is not enough, usually it requires a lot more."

Some of the training and workshop programs charge tuition to participants to help defray the costs associated with organizing the event and providing for speakers and materials. As one interviewee noted: "In some way the fee seems astonishingly high, but there are a lot of costs." On the other hand, some organizations like the WMO-WCRP have integrated policies that "allocate a certain portion of the funding for those [training and workshop] efforts towards inviting and supporting early career scientists, graduate students, while also paying attention to early career students from developing countries and regions of the world." For example, the WMO-WCRP set aside $20,000 for one capacity building workshop in Seattle to help early career scientists and graduate students to attend.

Several organizations, including IRI, have taken advantaged of modern telecommunications advantages to promote distance learning for developing country scientists to build their capacity while keeping costs down. For example, the IRI online learning models range from basic content (i.e. climate forecasting, downscaling from global to regional climate models, and climate predictability) to expert modules (i.e. using modeling software, data reference systems, statistical tools, and so on). One of the more widely used capacity building tools developed by IRI is the online Climate Predictability Tool that “help[s] create a forecast or prediction in a more rigorous way” to help developing country scientists working with local data. This Tool took a decade of incremental development to reach its robust form today. Over 8,000 downloads of this Tool have been recorded, and in-country workshops have been held by IRI in a variety of developing countries to train local scientists on how to use this tool.

The specific target of trainings and workshops for capacity building also vary, with most simply focusing on individual developing country scientists. However, the CCAA Training Workshops have an explicit objective of using individual trainings and workshops “to build *a strong cadre of institutions* able to assess and integrate climate adaptation issues into long-term strategic development planning and expand the community of adaptation practitioners” (IDRC, 2012; italics added). There is additional value-added to the CCAA Training Workshops because they took place across Africa and the participants were selected from existing CCAA projects on the Continent.

The USAID Global Climate Change Program (GCCP) completed a massive multi-year capacity building series of approximately 10,000 workshops, trainings, and seminars between 1998-2002. Over forty countries were involved, with key countries including Brazil, India, Indonesia, Mexico, Philippines, Russia, and South Africa. These countries were selected as being some of the largest greenhouse gas emitters that were perceived to have land-based carbon sequestration potential. An example of one such USAID project is the West Africa Land Use and Land Cover Trends project, which included four workshops on mapping and monitoring to enhance local capacity of 140 scientists in the region to enable them to effectively participate in this research project. Based on its extensive experience, USAID identified the following “[l]essons learned and best practices” for climate change-related capacity building programs:

- **For on the ground, lasting results, projects must include training components so that host country nationals will be able to manage and maintain the project.** For this to occur, there must be incentives for the host country practitioner of the project to become its manager.

- **Leveraging works best when all donor partners are present at all stages of a project from its definition and design through its implementation.** There is a need to build institutional partnerships in developing countries between donor parties, country officials and the private sector.
- **Replicating model projects has proven to be a cost effective and time effective means of bringing the successes and lessons learned from one country to another.** Care must be taken to tailor the projects to the specific needs of the country.
- **Projects that are developed jointly by several organizations must be housed with one specific organization.** This approach will give one group the ultimate responsibility to supervise the successful implementation of the project.
- **It is preferable that policies needed for project implementation be in place before the projects are implemented.** However, project development and policy/regulation formulation activities can concurrently be implemented. It is important to note, though, that without the appropriate policy environment, projects will not be sustainable (USAID, 2012; bold in original text).

Sound pedagogical approaches need to be factored into how capacity building training and workshops are structured in order for them to be effective. As one interviewee explained: "From my experience, what doesn't work is going in and having a show-and-tell. Here's what climate is, and here's what you need to do to change things. There needs to be a real hands-on approach, workshops, a focus on real issues that are prevalent."

In many instances, partnerships between organizations were used to deliver capacity building programming. Notably, the APN and START collaborated to support climate change research and capacity building workshops at a regional level throughout Asia. The focus of these activities related to five major thematic areas, namely: changes in atmospheric chemistry and its effects, climate variability and change, biodiversity, human activities in earth-system modeling, and water cycle research (START, 2012c). Given that capacity building workshops and training are directly related to APN-supported research collaboration, these are later projects are described in further detail in the next section below.

3.3.2.3 Collaborative research

The AIACC initiative, IAI Collaborative Research Networks Program, various IGBP research projects, APN's Annual Regional Call for Proposals (ARCP) as well as Scientific Capacity Building/Enhancement for Sustainable Development in Developing Countries (CAPaBLE), and START's Fellowships and Visiting Scientists program have supported collaborative research initiatives and exchanges involving developing country scientists from multiple countries. These research projects have been funded, at least in part, as a tool for capacity building in action. These projects view engagement in scientific research as required to effectively build capacity, rather than stand-alone trainings or workshops that lack an applied component.

The overarching philosophy of the AIACC was that capacity for scientists is best built through engaging in actual research projects with other scientists. Funding, training, mentorship, and networking of developing country scientists were provided through the AIACC to support three-year multidisciplinary and multi-country research projects that are designed by the program participants. The AIACC selected 24 "regional study team" proposals, out of a total of 150, through a peer-review process. The selected 24 research projects involve 235 developing country scientists and more than 60 graduate and undergraduate students, representing 46 countries and involving collaboration between approximately 150 stakeholder institutions (AIACC, 2012). Each regional study team was provided with a total grant of between US$100,000 to US$225,000 for a three-year term (AIACC, Undated). The ambitious goals of the AIACC included peer-reviewed publications by participants, increasing the number of developing country research working on climate change, and increased participation by developing country scientists in future IPCC assessments (AIACC, 2012). An interviewee described the tremendous success in achieving these objectives as follows: "There were over 100 peer-reviewed publications that came out of our project, and over 200 in total publications including book chapters and reports." The key to the project was the collaborative nature of the activity and the multiple opportunities for capacity building through doing.

One of the AIACC donors (IDRC) has an approach to grants for research that it calls "grant plus", providing not only funding, but also "services like access to library, data sources, partnership development, [and] IDRC training on finance and administration", according to an interviewee.

In the Americas, the IAI Collaborative Research Networks Program II (2006-2011, with a no-cost extension to mid-2012) funds 13 projects which each involve scientists from at between four to eight countries in the Americas. Each project receives approximately US$1 million in funding from IAI, and most aim to raise an equivalent amount of funding from other sources. As the program name suggests, it is an extension of an initial phase of collaborative research networks projects administered by IAI (from 1999-2006). These research networks are designed "to promote research cooperation and exchange of information in an integrated way through interdisciplinary studies and international networks" (IAI, 2012b). In addition to these major grants, IAI also provides funding for early career scientist research grants of several hundred thousand dollars each.

The IGBP funds numerous "core" research projects and initiatives, many of which have capacity building components integrated into them. For example, the Land-Ocean Interaction on the Coastal Zone (LOICZ) project includes specific capacity building components such as: Masters programs for members and staff participating in the project, international workshops, summer schools, field trips, hosting graduate students and interns, and holding training seminars and courses (IGBP, 2010).

Other significant collaborative research initiatives include two programs administered by the APN. These climate change research awards are available for scientists in the Asia Pacific region, with funding from the APN and the U.S. Climate Change Science Program/U.S. Global Change Research Program (through START). Firstly, the Annual Regional Call for Proposals (ARCP) funds research that contributes to the scientific basis for policy-making. “Capacity enhancement” for leading scientists and “capacity development” for early career scientists is being pursued by the APN through the ARCP (APN, 2012a). Secondly, the Scientific Capacity Building/Enhancement for Sustainable Development in Developing Countries (CAPaBLE) project focused on scientific capacity development, science-policy interface, as well as awareness raising and knowledge dissemination related to climate change. Phase I of CAPaBLE ran from 2003-2006 and involved 28 funded projects, with an evaluation completed in 2008. In this first phase, the CAPaBLE initiative trained 300 scientists and published over 50 peer-reviewed publications (APN, 2009). Calls for Comprehensive Research Proposals under the CAPaBLE program are intended to occur every three years, with the latest call for proposals in 2011 (APN, 2012a). The first criteria considered by the APN in evaluating proposals under the CAPaBLE program is the “quality of collaboration”, which requires developing country participation. In 2011, the average ARCP grant was US$45,000 and the average CAPaBLE grant was US$40,000 (APN, 2012b).

At an individual scientist level, the START Fellowships and Visiting Scientists program (1995-2006) supported senior scientists in developing countries to travel to major international laboratories to learn about cutting-edge research, and build long-term linkages both between individual scientists as well as their institutions. This twelve-year program, with a total of some 170 awards granted, was considered by START to have been “very successful in increasing the number of developing country scientists who contribute to global change research” (START, 2012d). The African Small Grants program administered by START (2003-2009) also provided one-year grants of up to $15,000 per grantee to support research on global environmental change in Africa. These grants were intended to encourage African scientists to participate in global climate science research opportunities.

3.3.2.4 Organizational support

Very few of the organizations reviewed had any programs that were specifically aimed at building capacity of organizations in developing countries that address climate change at the institutional level (i.e. universities, independent research institutes, governmental agencies and departments, national science academies/societies, and civil society groups and non-governmental organizations). This is despite the fact that the Tenth Session of the Conference of the Parties (COP 10) decision on capacity building for developing countries (non-Annex I Parties) identified such support as “key factors that should be taken into account” as follows (UNFCCC, 2004):

(a) To make institutional capacity-building a priority for the creation and strengthening of basic institutional infrastructure
(b) To raise awareness at various levels on climate change issues and increase the involvement of national governmental organizations in capacity-building activities.

The WCRP’s Capacity Development for Adaptation to Climate Change and GHG Mitigation in Non-Annex I Countries (C3D+) project is specifically focused on increasing the capacity of developing country institutions that conduct research and training related to climate change adaptation and mitigation. The approach taken by the C3D+ is to focus on developing centres of excellence in the following countries: Senegal, South Africa, Laos, Thailand, Sri Lanka, China, and Samoa. In turn, the strengthened institution in each of these countries provides regional training for improving capacity to address climate change, reaching together approximately forty countries. The C3D+ initiative has also developed publicly accessible materials to help “train the trainers”. The goals for the C3D+ for 2009-2011 are: to train 2000 to 3000 people in developing countries, hold 12 workshops, increase the capacity of supported institutions (e.g. a 20-person computer lab in Cape Town, South Africa), increasing the international work of supported institutions, and help develop and test tools for climate risk screening for decision-makers (C3D+, 2012).

IGES has several research projects that seek to build capacity of educational institutions throughout Asia to enhance the capacity to address environment and sustainability issues. First, the National Law and Policies project reviews and promotes approaches by national governments in the Asia-Pacific region to providing environmental and sustainable development education. Second, the Capacity Development – Human Resource

Development in Higher Education project is designed to enhance the human resources capacity to address climate change by proposing a "sustainable mechanism of capacity development in higher education" (IGES, 2012). One of the specific initiatives in this project is the "Vision for Environmental Leadership Initiatives for Asian Sustainability in Higher Education", which was released in 2008 and widely disseminated through various publications and symposium: "[t]he Vision shows several important concepts which needed to promote environmental education widely through higher education and to have cooperation between universities, and business and industry sectors for introducing actual experimental opportunities through field works and internships" (IGES, 2012). Third, the Assessment of Education for Sustainable Development (ESD) Policy project aims to "develop ESD indicators at [the] local level to provide a clear guidance to ESD decision-makers including policy researchers in relevant sectors, school governors, practitioners in actual fields" (IGES, 2012). These programs have included workshops held in cooperation with the UNEP and UNESCO throughout the region, including in Thailand, China, and Japan. While the focus of these IGES programs is on the environment and sustainability broadly, it is an example of a high-level organizational support model to develop capacity to address climate change through enhancing and strengthening one such institution (i.e. universities).

The IDRC also actively supports building the capacity of institutions in developing countries to address climate change, most notably in Africa. In November 2011, the IDRC announced C$10 million in funding for the African Adaptation Research Centres (AARC) initiative, over three years. Under this program "seven centres of research excellence are supported to strengthen the ability of African researchers to guide decision-makers in setting priorities and developing national adaptation strategies that protect people, communities, and livelihoods most at risk from climate change" (IDRC, 2011). The centres of excellence that will receive funding include the following:

- Integrated Sustainable Development Initiative, Benin: $823,000 to build resilience in local communities threatened by food insecurity and rural poverty due to climate change;

- Regional Institute for Population Studies, University of Ghana, Ghana: $1,399,000 to inform adaptation strategies that protect the health, livelihoods, and food security of people living in Ga Mashie, a poor coastal community in Accra;
- University of Alexandria, Egypt: $1,296,200 to establish an adaptation research centre in the Nile Delta, one of the regions in the world that is most vulnerable to climate change;
- Sokoine University of Agriculture, Tanzania: $1,338,300 to focus research on climate change adaptation strategies for agriculture and water resources in Ethiopia, Kenya, Sudan, and Tanzania;
- Institut International d'Ingénierie de l'Eau et de l'Environnement, Burkina Faso: $1,275,700 to reduce the risk of food insecurity to farmers from climate change, particularly in the Sahel area, which has experienced a marked decline in rainfall and a high degree of variability to the start of rainy season;
- Food, Agriculture and Natural Resources Policy Analysis Network, South Africa: $1,499,800 to encourage research-based food security policies in the context of climate change by linking researchers and policy makers in South Africa, Malawi, Lesotho, and Swaziland;
- Kenya Agricultural Research Institute, Kenya: $1,123,200 to support a greater understanding of climate risks and, in response, develop innovations to improve agricultural productivity (IDRC, 2011).

3.3.2.5 Networks: regional and global

The importance of support for regional and global networks of scientists as a mechanism for informal or indirect capacity development was recognized by several interviewees, and is reflected in many programs discussed above as an important side-benefit. As one interviewee stated: “A major part of the reason why [capacity building] is important is that climate change is a problem that is global, affects people everywhere and its solutions will require collaborations of different nations and institutions that are international in scope, local groups working across different boundaries."

Many of the organizations in this study deliver specific capacity building programs as discussed earlier, but are themselves fashioned as networks of individuals who are the primary participants, with an often modest secretariat that administers the organization's programs and manages its finances and reporting. In other words, it is notable that many organizations engaged in capacity building for developing country scientists are not traditional centralized organizations with a large staff of their own. Instead, they rely on a small cadre of staff members to run the basic operations, with substantial involvement from scientists who are full-time academic researchers or are on secondment from government agencies.

Several organizations, including START, IAI, IGBP, IHDP, IGES, UNEP, CCAA (IDRC-DFID), and the APN, have actively developed and supported networks of climate scientists to enhance the capacity and potential impact of developing country scientists to contribute to regional and global efforts to address the climate change problem. It is not a rare occurrence for individual scientists in developing countries to be involved in more than one of these networks. For example, one interviewee explained that frequently individuals participating in START are also members of regional "sister" organizations such as IAI or APN.

At the global level, another linkage between these organizations is the Earth System Science Partnership (ESSP), a collaboration of four international global environmental change research programmes: DIVERSITAS, IHDP, IGBP, and the WMO's WCRP. ESSP Partners also collaborate closely with IAI and the APN, while START acts as a capacity building partner (ESSP, 2012). This partnership supports the undertaking of Integrated Regional Studies (IRS) to contribute to Earth systems science through both local scientific understanding as well as knowledge of regional-global linkages. Each of these partners also organizes research and capacity-building initiatives and assists in the establishment of scientific networks in their regions.

To enhance developing country participation in such networks, the IAI Program to Expand Scientific Capacity in the Americas (2000-2003) offered grants of between US$15,000 to US$30,000 for small collaborative research projects involving developing country scientists in the Americas (IAI, 2012b). It is notable that in 2003, as discussed above, IAI also began to physically locate its Training Institutes in developing countries as opposed to its prior practice of holding them exclusively in the United States.

The IGBP, which originally launched START, itself has been actively developing regional networks of scientists to promote capacity building and enhancement. The IGBP has National Committees in at least 77 countries that encourage scientists to participate in research and regional activities to build capacity at national and regional levels. These IGBP national committees, in turn, participate in regional networks such as APN, IAI, and “a new regional global change network in Africa (AfricanNESS)” (IGBP, 2010). A developing country scientist has chaired the IGBP in recent years and most of the national committees are in developing countries, which also contribute financially to IGBP’s budget.

In many instances, these organizations develop specific networking opportunities as an add-on to their other capacity building programs, such as enabling beneficiaries of scholarships/fellowships or collaborative research grants to become better acquainted with other participating developing country scientists and their research activities. For example, the AIACC program collaborative research study groups (discussed above) are encouraged and supported to engage in networking among the various groups. Similarly, the IHDP’s Biennial Workshops are designed to develop and sustain networks of participating scientists through these periodic face-to-face interactions.

While APN and IAI have been successful in building networks of scientists in the Asia-Pacific and Americas, respectively, there have been failed attempts to establish a regional network for developing country scientists in Africa. One interviewee attributed the problem to the lack of local direction and management of the network: “a network called

‘Enrich’ was to be for Europe/Africa. The Enrich network turned out to be a parachute network with European dominance, and it has since died.”

Despite this failure, more recently, as part of the CCAA (IDRC-DFID) initiative, Learning Forums and AfricaAdapt are two programs designed to provide opportunities for knowledge sharing through providing networking opportunities for developing country scientists in Africa. For example, a recent CCAA Learning Forum held in Nairobi involved 17 participating researchers from Benin, Kenya, Malawi, Senegal, Tanzania, Zambia, and Zimbabwe – each of whom were involved in one of eight different CCAA projects. In 2009, the CCAA launched AfricaAdapt as a pan-Africa networking program that combines online technology with face-to-face interactions. The AfricaAdapt website currently has over 600 members and provides a portal for members to access media stories related to climate change and climate science, engage in online discussion boards, allow members to contact each other, as well as provide information about face-to-face networking events. Its aim is not only to enable researchers to connect and communicate across vast distances, but also to involve policy-makers, civil society organizations, and local communities into the network as well.

The IGBP Secretariat also secured funding for developing country scientists to participate in conferences and workshops at the global level to enhance their scientific capacity to address climate change. These face-to-face networking interactions are considered to be a more effective, albeit more costly, means of facilitating networking of scientists. One interviewee recognized a key limitation of the more typical approach of online networking as follows: “Virtual networks are very good to enhance the connectivity of people, to deal with inter-disciplinary problems, to deal with regional problems, to increase South-South scientific collaboration, they are working. . . . But these are based on existing research groups . . . they cannot create things out of thin air. They cannot create capacity where it does not exist. They cannot hire people to develop a sustainability research lab. They do very well with things existing, on a very thin budget.”

Other initiatives have been less about networking individual scientists, and more focused on networking institutions and countries to build capacity to address climate change. The UNEP has developed a series of global and regional networks related to enhancing capacity to share climate data and information between countries. For example, the Global Environmental Outlook (GEO) network is comprised of 34 regional institutes that engage in integrated assessing and forecasting from a multidisciplinary perspective. At the regional level in Africa, the UNEP also sponsors the African Environmental Information Network (AEIN), which is described as "a multi-stakeholder capacity building process that aims to harness and enhance access to information and knowledge to support the management of Africa's environmental resources as assets for sustainable development" (UNEP, 2012a). The AEIN began with 13 countries in Africa as a pilot project "to enhance accessibility to more reliable environmental data and information at [the] national level for the environmental assessment and reporting in the region" (UNEP, 2012a). At the global level, the UNEP supported the Infoterra network of 177 national focal points (e.g. Ministries of Environment or environmental agencies) that is designed to enhance public access to national climate information.

3.3.3 Program selection and evaluation

3.3.3.1 Identification of countries of focus for capacity development

Decisions have been made in each of the capacity building initiatives about geographical scale. Some focus on a select list of priority countries, while others take a regional outlook or global approach that includes both developed and developing countries. Allocating scarce funding for scientific capacity building is a challenge facing donors and implementing organizations, which one interviewee described as a "strugg[le] with who is most vulnerable and how to place priorities." Limited funding availability forces organizations to make difficult choices. As noted by an interviewee: "there's a[n ongoing] discussion on whether we spread our money out, or focus on a few countries and try to have a really big impact."

In practice, countries that are the focus of capacity building initiatives in this study were selected through a variety of approaches. Many global research networks operate solely within their membership base or region – then within that network they attempt to achieve balanced participation across their geographic scope so that countries are not favoured over others. Many organizations have frameworks in place for establishing their regional networks and prioritizing countries of interest. As one interviewee commented about their internal strategic organizational development processes: "[Our] changing [priority development] is an ongoing process. We're guided by corporate strategy, approved every five years by our board of governors, based on consultations with staff, recipients, broad international community of research for development, [and] actors linked to research in academia … We identify emerging priorities globally and then we have a program framework where our thematic lines are described and arise from the same consultation. Then our internal process involves consultation with research actors to identify key programming outcomes for each thematic area."

Others organizations use a more responsive and holistic approach to investing capacity building resources in certain countries of focus:

> "[It] has a lot to do with what else is going on in that country, maybe because we have so many different pots of money, so they may be a food security priority country, so we recognize that as climate change becomes worse, food security issues will also become more difficult, so it is important for us to put some climate change funding in there to preserve those development gains from the food security work. The climate change negotiations also have some influence, indicating that some countries are particularly vulnerable, so we're looking at the Small Island States, a lot of African countries, the least developed countries, and so on. Internationally recognized prioritization of countries is also relevant."

Geo-political considerations may also play a role in country selection. As one interviewee noted: "We don't support research in some countries, like Libya, Saudi Arabia because they are oil rich countries. Other countries we're not allowed to because of security. We can't support research in Darfur."

3.3.3.2 National program development and capacity self-assessments

Within countries, funding decision-making is becoming more decentralized, with specific decisions regarding how funding is allocated within countries often made by local staff "in dialogue with the host country government about what the priorities are." As described by one interviewee: "it may be decided in headquarters that a certain mission in Bangladesh will get $5 million for climate change adaptation, but then the decision about what is going to happen with that $5 million will get decided in Bangladesh between the [local] mission and the Bangladeshi government."

These important steps towards self-directed funding may be now more important than ever. One interviewee expressed frustration with needs prioritizations: "The manner in which priorities are set by funding agencies is not systematic enough. It should … start with an assessment of the needs that would be as independent as possible. It would be really useful to start with the real needs in the specific region where the capacity needs to be built." Another interviewee echoed this sentiment:

> "Generalizations [on the main barriers to capacity building] are difficult to make. You have to understand local context, institutional setting, organizational strengths and deficiencies, to work at the level the [local] organization is at. One of the main activities that needs to take place is a good assessment [of capacity] from the start. There is a gamut of limitations that can be experienced in a certain area, the capacity to administer funds, the monitoring and evaluation, writing, communication, there are so many different aspects. When you talk of research for development, you need to look at the situation in a particular context."

As a result of this growing awareness, funding for climate science capacity building is now often being primarily based on national needs assessments, emphasizing "the country specificity of responses to climate change and the need for countries to provide guidance themselves." This is important because, as one interviewee explains: "You can't make a broad assessment of the one area most needed in general. The issue with climate change is you can't generalize. Each country has its own needs." Holistic approaches are now being favoured, as the same interviewee explains: “It is somewhat myopic to look at one particular area and not holistically for capacity building needs in a country.”

Vulnerability assessments and national needs assessments are now being more commonly used as strategies to direct in-country funding. As one interviewee explains: “Some of the initial funding [within a country] may be used to do a vulnerability assessment and stakeholder training and dialogue and depending on what priorities emerge from that, the next round of funding will go to actually implement those other projects that would be infrastructure projects or [etc.].” Another interviewee elaborated: “Given the extent of the possible impacts of climate change, with sectors, there are different communities that they’re trying to increase capacity. It depends for a particular project that one wants to achieve. Overall, the goal is for countries to be able to effectively identify the risks within their country and identify, given a large basket of approaches that have been tried, which would be effective in their particular context so that there is social learning from one place to another and to have the kind of environment where that can happen.”

UNEP offers National Self-Capacity Assessments (NSCAs) (UNEP, 2012b) where countries themselves can determine what capacity building is most needed, within an international framework: “Not every country has done this process, but some have. They have identified their needs.” IGES is another organization that also places a heavy emphasis on conducting a baseline needs assessment in advance of supporting capacity building initiatives: “the approach is a training-needs assessment that looks at knowledge and skill levels of the target people whose capacity you want to build”.

While the NSCA is a promising “flexible” and “powerful” tool (UNEP, 2012b), some interviewees raised concerns, however, about what could be called “assessment fatigue” by developing countries. Vulnerability assessments, while more common than national self-capacity assessments, still have implementation issues with some developing countries avoiding them, probably as one interviewee notes because: “they’re worried that if we spend the money available now on [a] vulnerability assessment, how do they know that there will be more money later to actually do something. So, [it’s] a lack of confidence maybe that we don't really follow through." Other issues with the quality of initial vulnerability assessments have occurred: "a lot of these countries have [previously] done things like [a] national adaptation plan of action, so I think they often feel like they've set priorities already and they've looked at it already, so why do [they] need to do it again. I think we feel like some of those were done a fairly long time ago, and some of them didn't involve [a] very wide range of stakeholders. So while we want to respect national priorities we don't necessarily feel like all of those are as good as they could be. We don't want to rewrite them for them, but I think we sort of want to encourage a more inclusive process."

3.3.3.3 Selection of research projects

There are an array of strategies used by organizations included in this study to decide which projects to fund and partners to involve in executing their capacity building strategies. Open calls for proposals are ordinarily used to attract research participants, with the following evaluation criteria being commonly used to assess projects, in addition to assessments of the individual researchers (as described below):

- Technical quality of research proposal;
- Evidence of sound project management;
- Development of monitoring and evaluation assessments;
- Evidence of professional research, and credibility and institutional linkages of the research team; and
- Quality and extent of stakeholder consultation.

Other factors influencing support for research proposals also include "available data to inform a problem, … interest not only from the technical community but the governing bodies in terms of interest in expanding their decision space, and access to people who can participate in some sort of a collaborative activity."

Sometimes closed calls for proposals can also occur when organizations are looking for research teams in specific fields. In such cases, program or research areas requiring support are identified along with other gaps and then specific participants are selected.

Organizations also at times employ a "grassroots" approach, where the priorities for partnerships or areas to work in arise when the "community-at-large identifies [the need for] having some conference, workshop, symposium or project field experiment."

3.3.3.4 Selection of individual participants

To select participants to partake in their programming, most organizations utilize a "competitive selection process" whereby opportunities are advertised and scientists and young researchers as well as at times other stakeholders, decision-makers and professionals working in the selected field are invited to apply. Researchers are often expected to have completed certain educational requirements (i.e. a M.A., M.Sc., or Ph.D.) and are typically required to submit an application package including Curriculum Vitae. Research opportunities additionally require the submission of a research proposal. Often there is a preliminary screening of applicants followed by a peer-review process and/or advisory panel evaluating the applications, which may consider the following criteria:[10]

- Academic background and experience;
- Grasp of the central issues, expressed in a Statement of Interest;
- Vision and strategy for applying concepts within a follow-up project;
- Home institution's support, relevance, capacity, and connection to target stakeholders;
- Applicant's influence within their institution, and potential for long-term impact;
- Proven record of research accomplishments;
- Merit of research proposal, plan, and objectives and references (if required); and
- Geographical representation, affiliation with an institution in a developing country.

In some instances, organizations in developing countries are asked to help by identifying or nominating individuals from within their ranks who would most benefit from, and be

[10] These criteria are a synthesis of those criteria used by various programs reviewed in this study, including the IRI Advanced Institutes, IHDW Biennial workshop, APN, IIASA Young Scientist Summer Program (YSSP), and IIASA Post Doctoral Program.

able to participate effectively in, the various capacity building activities. According to one interviewee: "Coming from the outside, we have to rely a lot on the knowledge within the organizations about the individuals who are best for the training, the areas for capacity." Challenges can arise given the vastly different starting point of some participants at these workshops, however. One interviewee described such a situation as follows: "In some cases, for example, you might be dealing with very eminent scientists in agriculture but they don't have any experience in dealing with climate change. In other cases, you might be talking about researchers who are not very established professors, but they have an interest in the climate subject. You're looking at people with a great deal of different needs when it comes to capacity building."

When specific technical trainings and workshops are held, often the selection criteria may be specifically tailored to each event. As one interviewee noted: "When we ran the climate modeling event, one criteria was a sufficiently good understanding of statistics to link to model to events in the field, and understand uncertainties. If you didn't understand basic statistics you weren't invited. There were other workshops on disaster management where the criteria were totally different – we had people from the Catholic Church attend, where people turn to in the region during disasters."

3.3.3.5 Program monitoring and evaluation

There was overwhelming consensus among interviewees that meaningful monitoring and evaluation of these capacity building programs would be beneficial, but none of the programs appeared to have rigorous, outcome-based indicators for evaluating success. As one interviewee stated: "We know that capacity is needed, but how do we know when it's not needed, when it has been successful. Follow-up is crucial." Another interviewee echoed this, saying: "At the end of the day, we want to work ourselves out of a job." Effective assessments can assist organizations in knowing if they "should still be there", or if capacity has been built and other actors exist to take their place, allowing them to allocate their resources to others in need.

Many interviewees noted how monitoring and evaluation for capacity building is an emerging area of concern and interest within the field. As one interviewee characterized it: "The whole logic of metrics, the indicators for successful capacity building needs to be developed. It is something we're looking at but we're not sure how other institutions deal with that." Others expressed avid interest in the results of this study and the approaches other institutions are using: "We're very interested in learning from your research… [Monitoring and Evaluation] is something that we'll be doing for the next decade and it would be great if we could collect the information to evaluate effectiveness as we move into the future to make it better."

This issue tended to elicit differences within organizations and between partners. As one interviewee remarked: "We have a problem in determining what successful capacity building looks like… For instance, one government is happy with statistics: how many people we trained. Other stakeholders want to know what happened when those people went back to their institutions."

Many programs did not have any formal monitoring and evaluation components beyond basic information on the number of projects completed, a count of the number of participants, financial reporting, and feedback from participants immediately after completion of the particular capacity building activity, with some of these programs only recently begun. None of the organizations assessed the knowledge level of participants both before, and after completion, of the capacity building program to determine if participants demonstrated enhanced understanding and retention of the relevant subject matter or skills. However, one participant commented about the practice of assessing participant knowledge (i.e. testing), noting that in certain national contexts "there's a lot of sensitivity with passing or not passing, and what the implications would be for the person." Some programs included application-based exercises so that participants had the opportunity to apply the knowledge and skills being imparted during a particular training workshop (e.g. proposal writing or using a Geographical Information System (GIS) application). Other organizations attempted to stay in contact with past participants of their capacity building programs, with varying levels of success, and obtained some anecdotal information about their subsequent research publications and employment status. As one interviewee noted: “The manpower, human resources, in follow-up is a lot. You can’t rely on the person you trained to stay in touch.” Another interviewee noted that capacity building activities may increase the mobility of participants, making them more difficulty to track: “Sometimes you’ll train someone, their status is elevated and then they’re hired out of their department.”

None of the organizations that focus on capacity building for developing country climate scientists had implemented a formal system to track these individuals who had been the beneficiaries of capacity building programs. An example of an ongoing “tracer” study that could be helpful for graduate fellowship programs was identified, however, in the open source research of the World Bank’s general graduate fellowship program. This scholarship program tracked the career progress of recipients over a 20 year period, using the following measures:

- attained their degrees successfully and benefited from their academic programs;
- returned to their home country or other developing countries;
- achieved recognition for their enhanced skills, progression and mobility, higher income, and better grades and promotion in their jobs; and
- engaged in senior professional and managerial positions that provided them with the opportunity to disseminate their newly acquired skills and knowledge, and contributed to the overall socioeconomic development of their own country or of other developing countries. (World Bank, 2012)

Some interviewees believed that the costs and logistical complexity to conduct longitudinal outcome-based evaluation of capacity building programs directed at developing country scientists would be prohibitive. There was the additional concern that it was problematic, or even impossible, to attribute the future success (or lack thereof) of a developing country scientist to any one particular program, given the numerous and diffuse factors that undoubtedly have an impact on the productivity and profile of any one scientist and issues with proving causality in a retrospective cross-sectional survey design.

Notwithstanding these concerns, interviewees mentioned several potential indicators for success in evaluating capacity building programs for developing country scientists, including:

- Securing academic and professional appointments, and subsequent career advancement;
- Research productivity based on peer-reviewed scientific publications, research grants obtained, and mentorship and supervision of graduate students;
- Ongoing involvement in regional climate science networks;
- Subsequent requests from participants or national governments for more capacity building programs (i.e. "repeat business");
- Building capacity in their own countries;
- Participation and research presentations as local, regional and international scientific conferences; and
- Participation in international organizations and authorship in leading global climate science initiatives, like the IPCC.

Some organizations have experienced success in pursuing some of these goals, namely increasing peer-reviewed publications and IPCC authorship participation. As one interviewee stated:

> "There are three levels [at which we monitor and evaluate our progress]: first, at the project level, each has a monitoring and evaluation framework. Second, a monitoring level – each project is monitored on a financial level, deliverables, achieving what was contractually obliged. Third, at the program level, did our researchers get publications in international peer-reviewed journals… Our project partners have given 120 presentations at international research events. We have a lot of [peer reviewed] publications, at the moment, 37 publications for 15 projects. .... Also, [f]our or five research partners have been invited to be IPCC authors."

It was acknowledged by some interviewees that these so-called indicators are merely "proxies" – they can effectively measure the financial and human resources and contributions made. However, assessments "in terms of the capacity that was mobilized and sustained, that is much harder to measure." Evaluating success in achieving this foundational objective has been elusive for most of the organizations participating in this study. A further complexity is that evaluation metrics likely have to be adapted to the particular type of capacity building activity in question. For example, evaluating a collaborative research network for developing country scientists would require different indicators than evaluating a one-time training session for individual scientists on running a particular statistical software application. Another interviewee mentioned that standardizing evaluation indicators was a huge problem in itself, if wanting to compare projects or initiatives across institutions, saying "[b]ecause there are no common metrics, one person's metrics could be totally different from another."

One organization was atypical for citing the impact of its overall program participants in actually affecting change to national laws and policies related to climate change. An interviewee described a few such examples as follows: "In terms of outcomes, IAI project results and information knowledge is being used now as a legally binding official tool for deforestation and land use decision in Brazil, IAI outputs have made their way into laws in Chile, biodiversity has been included in some of the climate change plans of Andean countries, the city of Medellin has adopted our methodology and hired some scientists from our grants into public health for communicable diseases. One IAI veteran is now a science advisor in the White House."

External reviews and outside consultants have been relied on by some organizations to engage in multi-year program evaluations. Many interviewees considered that research on how to better monitor and evaluate capacity building programs would be very helpful. As one interviewee stated, "There are so many ways of measuring effectiveness. The question is what category do you really believe is best indicator of impact and effectiveness and how do you measure that?"

3.3.4 IPCC Assessment Reports

The IPCC has been widely regarded as the leading international body for the assessment of climate change. Its work has been generally acknowledged as globally authoritative, garnering recognition for its significant achievements in 2007 by being awarded the Nobel Peace Prize "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change" (IPCC, 2012a). Within its mandate, the IPCC "reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. It does not conduct any research nor does it monitor climate related data or parameters" (IPCC, 2012b).

Additionally, "[t]he work of the organization is … policy-relevant and yet policy-neutral, never policy-prescriptive" (IPCC, 2012b). One interviewee added to this, saying that the IPCC: "produce[s] assessments that are policy-relevant but policy neutral. The challenges are the complexity and the real issue of how well humans can understand a world that will look different from a world that looks like today."

The IPCC has recognized for almost a decade that developing country scientists have been under-represented in its ranks (as noted above; Ho Lem *et al.,* 2011; IPCC 2009), although the organization has made efforts to improve the situation. According to the IPCC, "[t]he participation of the scientific community in the work of the IPCC has been growing greatly, both in terms of authors and contributors involved in the writing and the reviewing of the reports and of geographic distribution and topics covered by the reports" (IPCC, 2012a). As one interviewee explained about historical processes in the IPCC:

> "At the end of the [Assessment Report (AR)] 3, the IPCC authors were learning there was insufficient participation of scientists from the developing world, and that there was a need for increasing scientific capacity in the developing world. So it was a specific goal to train scientists for participating in the IPCC. One of the last author meetings of the AR3 IPCC, afterwards [the IPCC] convened people to brainstorm how

> to build capacity in developing countries. An outline of a proposal was put together at that meeting in 2001 in Portugal."

Since that time, the IPCC has cooperated with several international capacity building organizations. Within the IPCC itself, however, "[i]t is only informal, because capacity building is not part of the IPCC mandate," according to one interviewee. Despite this position, the organization has taken modest steps to engage developing country scientists at each stage, from nomination of potential authors, the selection process, building capacity of selected authors, and conducting outreach after the completion of assessment reports. Informal capacity building is also believed to have occurred by fostering collaboration between developed and developing country scientists, both in the IPCC assessment report process where there is "a kind of exposure to the international state of knowledge and literature", as well as through some joint publications after the completion of the assessment reports. One interviewee explained further:

> "[E]verybody is aware of the importance of capacity building informally, [and the IPCC] is probably contributing to a large extent to capacity building even if it is not under an explicit label… The fact that [the IPCC] integrate[s] [developing country authors] into the writing teams probably helps them to become better. It is not labeled capacity building, but it probably helps in an important way for the scientists participating in the exercise."

The IPCC Secretariat has encouraged nominations from developing countries of their scientists for participating in various assessment reports. Scientists are nominated by "national focal points" to be considered as IPCC authors. One scientist explained that within Working Group II, the IPCC received over 1,200 authorship nominations for Assessment Report (AR) 5. Each Working Group has a "bureau to determine the author teams" and the Working Groups work with their bureaus to review the nominations and "identify the most appropriate, the best people, taking into account gender and geographic balance." The author selection process was described in further detail by one interviewee as follows:

> "There is among the rules that the IPCC has to follow in selecting authors explicit mention of the need for required disciplinary competence but also to have regional balance in the writing teams as much as practical. Of course, sometimes there is a tension between the need for geographical balance and disciplinary competence. So if you have a chapter in Working Group I on detection and attribution of climate change to various factors, a difficult area, it may prove difficult to find even one specialist in Africa, for example. So there are exceptions and areas where it is more difficult where it is really difficult to achieve that balance."

The role of national focal points is thus a critical link between individual scientists and the IPCC. However, in developing countries the national focal points are not always fully engaged or effective, and in some cases "[t]here are countries where the focal point does not put anyone forward at all", according to an interviewee. It was also acknowledged by this interviewee that "[i]t is hard in [developing] countries that don't have some national science council or national academy of science" to identify appropriate scientists. For example, in some instances, national focal points in developing countries are meteorological offices that do not have strong ties to the scientific research community and may not know the best individuals to nominate for IPCC participation. In such situations, even where there are qualified developing country scientists there is a risk they will be overlooked by the IPCC because these individuals are not known to their national focal points."

Sometimes, international networks and institutions can play a role in the recruitment of contributors. Historically, the IPCC has encouraged START to provide assistance to scientists to become known to their national focal points to increase their participation. START has also been enlisted to directly submit as many as 30 individuals to be nominated as authors to the IPCC bureau, who then reviews the nominations and makes the final decisions. If an author is nominated in this manner, START then asks them to "contact the IPCC focal point in their country to let them know that an international organization is nominating them, and also to ask their national government to include their names in their nominations."

Once developing country scientists have been selected to participate in an IPCC Working Group, there are some efforts to "increase the capacity of developing country scientists to be fully engaged in the assessment". For example, IPCC Working Group II was planning on holding regional capacity building meetings in 2011 in Africa, the Small Island States, Central and South America, and Asia where all authors for the region would be invited and the IPCC would cover travel and per diem costs. At each session, four capacity building meetings would be held, lasting two and a half days each, covering a range of topics from "the difference between review and assessment, the process of an IPCC report, the kinds of things they would see across contributions for [the next assessment report] AR 5."

Developing country scientists participating in IPCC Assessment Reports are afforded some additional support. For example, the IPCC has negotiated access for these scientists to "a very wide range of scientific literature in the field related to the working group" that would otherwise be costly to access, and is working with them to identify relevant publications and reports in their local language. Financial support is also provided to these scientists to participate in mandatory international meetings. As one interviewee described: "For each Working Group, we have four lead author meetings they are required to attend. For developed countries, they [the authors] pay for travel and per diem but not time. For developing countries, the secretariat has a trust fund to pay for travel and per diem but not time."

After the completion of IPCC Assessment Report, relationships that were built by scientists from developing and developed countries often continue thereafter. As one interviewee noted "people often work together afterwards on publications out of the chapter that they worked on." Additionally, upon completion of an Assessment Report the IPCC engages in outreach activities and regional meetings to help "build capacity for the next round."

The IPCC has grown increasingly aware of the challenges involving the participation of developing countries in the IPCC and at the 30th Session of the IPCC in Antalya, it was decided (Decision 7) to carry out an assessment of the "current shortcomings in involving adequate number[s] of developing/EIT [Economies in Transition] country scientists and to propose approaches to address this issue." (IPCC, 2009) As part of this assessment, the national Focal Points or Ministries of Foreign Affairs were surveyed in September 2009, with 38 responses received. The results of the survey confirmed that despite significant interest in participation, the lack of nominations of experts in developing nations by Focal Points is a significant problem. Below is a summary of the survey results from developing countries and EITs:

- 50% of respondents indicating that *no experts* were nominated by Focal Points in their countries;
- 80% of developing country respondents consider the participation of their country's experts in the "preparation of new scenarios in the AR5" to be insufficient;
- 100% of respondents reported that "improving capacity and expertise on climate change is an issue for all developing countries";
- Respondents unanimously agreed that "participation in the IPCC and the exchange of experience during the IPCC meetings enhance scientific capacity of the countries on climate change"; and
- Respondents also unanimously agreed that the organization of "regional meetings" could increase interest and participation in IPCC activities.

The recommendations arising from this study to increase the participation of developing countries and EITs are summarized below:

1. Consider ways to enhance the awareness of the Focal Points regarding IPCC activities by for example setting up communication and outreach initiatives. Additionally, encourage Focal Points and Bureau members to nominate more experts from developing countries/EITs;

2. Ensure that procedures for the nomination and selection of authors and reviewers are conceived in a way that facilitates the identification and selection of suitable experts from developing countries/EITs;
3. Consider ways to increase the provision of financial support for the attendance of more experts from developing and EIT countries to IPCC meetings;
4. Organize more regional meetings in developing regions;
5. Encourage the participation of experts from developing countries/EIT in the outreach process of IPCC products;
6. The IPCC/WG Bureau should encourage more involvement of young experts from the developing countries/EIT in the IPCC process;
7. Explore possibilities to facilitate DC/EIT country scientist participation in IPCC scenario development.

3.3.5 Challenges, gaps, and drawbacks

Interviewees identified a number of significant obstacles to achieving sustainable, long-term scientific capacity development to address climate change in developing countries. Foremost of concern were limited funds and other financial constraints, and insufficient climate science institutions in developing countries. Other challenges included the "brain drain" phenomenon, data access and quality, technology and research resource limitations, difficulties with downscaling/up-scaling of climate modeling, the interdisciplinary nature of climate change, navigating the science-policy interface, and issues related to operating across culture, language, and gender.

These challenges examined in detail below are general and pervasive concerns that interviewees had about building scientific capacity in the developing world. However, integrated throughout the discussions were references to the progress made in emerging economies, namely China, India, South Africa, Mexico, and Brazil, which have invested heavily in science and technology over the last fifty years and operate at a higher level of technological capacity than other developing countries.

3.3.5.1 Financial issues

Global funding for scientific capacity building for climate change initiatives is a significant challenge and has been cited by interviewees as the most frequent barrier for developing countries in contributing to address climate change. This chief concern about insufficient funding was succinctly stated by one interview in response to a question about what the major challenges facing capacity building for developing country scientists working on the climate change issue: “Lack of funding, there’s no money.” Developing countries in particular, often do not have the financial resources to “fund mitigation or adaptation efforts, to participate in science.” As one interviewee noted: “As a developing country, research will never be a priority. The percentage of research money to GDP will always be low, because they have a lot of things they need to spend their money on.”

Funding availability commonly faces significant political pressure with elected politicians “hav[ing] to focus on current needs, otherwise they won’t get re-elected.” Funding prioritization often also appears to be based on crisis aversion, especially in the developing world. The same interviewee explains: “Talking about Africa more generally, the prioritization of climate change adaption has really varied from time to time. There are HIV/AIDS problems, malaria, food security, and human security issues. So in some cases, climate change is not a priority, but in other cases there has been attention to it.” Another interviewee describes the situation as climate change “hazards” being only one of myriad hazards faced by the developing world: “In many communities they look at the most important problems and climate change can seem not as urgent when dealing with hunger, malnutrition, infectious diseases, and those perceived things in more need of immediate attention can crowd-out climate change.” Yet, understanding about the interconnection of climate change to other issues is being built as people make linkages between the reality of how “climate change can increase the risk and vulnerability [to] these other issues”: “if one talks about how climate change is linked and connected to these other stressors, [and] you’re not asking people to ignore day-to-day issues for this abstract and obscure notion of climate change, … [then m]ore groups then say ‘okay, it makes sense for us to look at climate change', in terms of how it relates to these other issues."

In terms of funding priorities in the developing world, scientific research funding has usually taken a backseat more generally. Interviewees believed that developing countries must start funding science initiatives as a long-term goal. As one interviewee explains: "If [developing nations] always depend on aid agencies [to] provid[e] support for science in Africa, that isn't going to go far. They need to see it has benefits and they have a responsibility to fund it. We see some countries like South Africa would are beginning to do that."

At the organizational level, the extensive time requirements to access funding have also been cited as a significant barrier in creating effective programming. As one interviewee explained: "For example, I helped write a proposal and it took 6.5 years to get the funding. That is pretty typical. Many people were taking 5-7 years to get a project through. It is quite challenging when you go into a developing country, where the whole process of building a proposal is meant to build capacity. You do all this work with a local consultant and partners, and 6 years later, that person is well done. Everyone is on track, but 6 years later you're starting from scratch."

Shifts in funding priorities have also caused problems in sustaining capacity building activities. For example, one interviewee described how one of the programs discussed above that provided graduate scholarships and post-doctoral fellowships was terminated after a donor changed their priorities after the recent global economic downturn. More generally, another interviewee described the problem as follows:

> "Donors, however successful a project is, their attention shifts. If you go back and say you want to do something similar, they say they want to do something new and different. They're constantly shifting their priorities. A lot of groups in the developing world have to be driven by where the funding is going. It is very difficult to sustain a coherent, cohesive set of activities when the funding is irregular and unpredictable and different

> emphasis each time on what the donors wants. In the developing world this creates extreme chaos, since core funding is often lacking, they're depending on new grants since they don't have secure funding to fund staff in between grants. That is a serious and substantial problem."

There has also been tension within the issue of climate science specifically as to which aspects should receive the highest prioritization. In particular, in the past there has been a tendency to focus on climate change mitigation first, with much less focus on adaptation to climate change. As one interviewee explains: "The reason there is such low capacity [of people with experience in adaptation is because] there was a general belief that if one talked about adaptation, one was giving up on mitigation. The breakthrough on that didn't come until Bali." Presently, there has been a shift in perception, but: "It has taken a long time to get through the negotiations that adaptation is as important as mitigation." As another interviewee provides additional insight: "Everybody now believes that we now have to pursue both adaptation and mitigation at the same time because we are committed to a certain degree of warming and the impacts of climate variability in the form of extreme events are felt more at the national and regional level. The nature of science is changing, the need for information has shifted from global to the regional level, … the need is there and we respond to that need, … therefore this is becoming a priority for us."

These changes may be none too late, as another interviewee notes: "In developing capacity for understanding the ways in which a place and people are at-risk and vulnerable to climate change and the various options, strategies that are most promising for adapting to climate change are the highest priority for most of the developing world."

3.3.5.2 Institutional gaps and limitations

Effective scientific capacity at the institutional level comprises: the effectual functioning of organizations, institutions and agencies involved in climate science and knowledge at multiple levels and sectors within society, as well as support from robust policies, legal frameworks and evaluation systems. The web of institutions that interviewees considered to play an important part in climate change science include:

- Universities: undergraduate and graduate education at the Master's and Ph.D. level, Faculties, research laboratories;
- Governmental: agencies and departments (such as meteorological offices, Ministries of Environment, Agriculture, Health, etc.), national science policies, scientific research funding agencies, and promotion of national science academies;
- Civil society groups and non-governmental organizations (NGOs); and
- Independent research institutes.

Unfortunately, in developing countries, some of these institutions are non-existent while many of those that do exist are not effective and suffer from a lack of institutional capacity to effectively contribute to climate change science. One interviewee described the situation in compelling terms:

> "In general, there are a series of factors or barriers that limit not just scientists, but countries' ability. It is somewhat myopic to look at one particular area and not holistically for capacity building needs in a country. So when countries look at this, they try to look at it in a holistic manner. But some of the areas identified involved lack on institutional capacity building, basic infrastructure, lack of awareness tied to climate change issues, lack of involvement by national governments, lack of appropriate venues for exchanging best practices, lack of capacity building to measure effectiveness of activities, there was also lack of financial and technical resources especially for least developed countries and Small Island States. Some parties brought up need for better financial and donor coordination. There was a big push by developed countries for harmonization of aid. Another piece was the weak institutional arrangements at the national level to really get down to implementing the 15 points [in Decision 2/CP.7 of COP 7, discussed in the introduction to this paper]."

In a specific example related to academic institutions, one interviewee pointed out that some African countries still do not have a Ph.D. program in the sciences at any of their universities; and several interviewees observed that Faculty members are expected to teach large lectures rather than focus on research. Academic salaries may also be restrictive. One interviewee remarked: “sometimes the scientists must have a second or third job to sustain their families.” The “general quality” and “level of organization of the education system in that country” can also present problems. One interviewee observed: “some of the teachers even in some universities are not at the level where a PhD student can develop their potential and do original research.”

Many interviewees felt the lack of institutions in their own regions was a major barrier for early career scientists to pursue a scientific education and career. As one interviewee stated:

> “The first major barrier is having the candidates to purse this kind of research. You know, believe it or not in some countries in Africa they don’t even have Ph.D. programs until recently or, still don’t have them, or [are] just in the process of putting those together. Second, once you have the candidates, you need to have the infrastructure and facilities for them to really do the research and have the resources and funding to do the research.”

A synthesis of the interview data reveals an inter-related set of challenges facing developing country climate science institutions that threatens the utility of capacity building programs, starting with funding, personnel, and governance issues. Without an effective home institution that is sufficiently funded and resourced, developing country scientists are unable to do their work. Interviewees noted that scarce funding might restrict scientists in their ability to attend conferences and impose addition administrative duties on scientists such as financial accounting, which can further restrict funding because international donors are skeptical of such arrangements. Research projects in developing countries have also suffered from a lack of institutional capacity due to weak governance, which can “exacerbate particular vulnerabilities”. As one interviewee explained: “One [project] suffered from lack of governance, faulty accounting, insufficient preparation of participating institutions, emergence of a conflict of interest.”

As one interviewee noted about funding constraints: “Some countries have no research granting organization, all money is external. I know a number of excellent researchers in Africa who move around a lot because it is so difficult to get research funding. You have to be willing to move around if you want to continue to do the research.” Furthermore, political turmoil in their countries can also cause developing country scientists to go abroad. For these and other reasons, the phenomenon of “brain drain” is a concern when scientists relocate permanently to developed countries.

When capable scientists do stay in their home countries, they are very much in demand. One interviewee expanded on this, saying “one of the challenges is that our partners in the developing world are individuals that are very capable, so they’re in high demand and pulled in multiple directions. … They had multiple grants in their institutions and need to be responsive to all of those, so that can be quite difficult.”

Institutional gaps constitute one of the foremost barriers to building scientific capacity in developing countries. As another interviewee noted: “You can do all the training in the world, training every scientist in the world, but if they don’t have the infrastructure to study the areas they’ve been capacitized in, that’s a huge problem.” Institutions are critical for providing logistical and technical support to scientists. Of several major institutional hurdles facing developing country scientists, one primary challenge identified is the insufficient access to reliable climate data. Even with reliable data, inadequate technology and research laboratories will prevent them from using and producing knowledge, including downscaling of international or regional climate models. Many institutions in developing countries lack an interdisciplinary outlook, or capacity to engage with policy and decision-makers that are needed to address the complexity of the climate change problem. Each of these institutional-related challenges have a direct bearing on the ability of capacity building activities to succeed in generating and sustaining enhanced local scientific capacity in developing countries, and are explored in detail later on.

Governmental institutions also play an important role in climate science including funding and other support they may offer to other institutions. Many developing countries have not yet established a coordinated national science infrastructure that include a national science policy, funding agencies for scientific research, and/or recognized independent national science academies to foster the professional recognition of leading scientists, and enable them to effectively contribute to public policy at the national and international levels. As one interviewee noted: “Let’s face it, a country like Guatemala until very recently, four or five years ago, didn’t even have a science funding organization.” As with many universities in developing countries, the organization of government departments similarly have been traditionally organized around discrete subject areas as opposed to bringing a multi-faceted response to various public policy challenges.

As mentioned earlier, ineffective national focal points also prevent qualified developing country scientists from being identified for potential participation in the IPCC. One interviewee described the importance of government in the process as follows: “One area where countries share a lot of concerns about lack of support is national coordinating entities or national focal points for climate change. There is a lot of attention on implementing agencies… but at a governmental level it is very difficult to coordinate since it comes from the private sectors, NGOs and such. There’s not one coordinating office. There’s a need for technical support, for infrastructure.”

Finally, the role of local communities, NGOs, and civil society was highlighted as less formal institutions that play a role in responding to climate change and liaising with developing country scientists. One interviewee described the importance of local networks and relationships as follows: “the communities where they had some sort of good organizational structure whether in local government, or NGO or civil society groups are a lot easier to work with because they have inroads in the communities and the trust of the communities and also knew how to communicate things appropriately. In places where those groups didn't exist, or weren't engaged or didn't see this as a priority, it was obviously a lot harder for us to work in."

3.3.5.3 Brain drain

The phenomenon of "brain drain" is perceived to have undermined the level of scientific capacity in developing countries, according to most interviewees. Brain drain was also the only potential disadvantage of capacity building activities directed at developing country scientists that was identified by interviewees. This term was understood by interviewees to refer to the relocation of developing country scientists to developed countries, and the potential for this flow to be increased as a result of developing country scientists becoming more mobile due to their increased scientific capacity. If brain drain were to result on a wide-scale basis due to capacity building efforts, it would thus undermine the primary objective of such programs – to generate long-term local scientific capacity *in* developing countries.

Notably, several interviewees drew a distinction between different types of capacity building, and their potential to either enhance or reduce the possibility of brain drain. For instance, while supporting developing country scientists to complete their PhDs at universities in developed countries may encourage those emerging scientists to remain in developed countries after completion of their programs, other forms of capacity building such as institutional support for laboratories in developing countries would have the opposite affect. Research grants that are fashioned to require a portion of funding to be spent in developing countries, including collaboration with developing country scientists, were also seen as promoting capacity building without contributing to brain drain.

There was near unanimous agreement that brain drain, if it is indeed a concern, is not the fault of individual scientists who are making rational choices about standards of living for themselves and their families, as well as decisions about where they can best advance their research agendas and careers. However, many young developing country scientists who have relocated to developed countries are also believed to have an ongoing affinity for their home countries. As one interviewee stated: “There’s a tremendous amount of idealism among scientists that attracts them back to their home countries.”

Brain drain was thus considered to be primarily an issue that should be factored into decisions by donors and organizations that run capacity building programs to ensure that their activities are structured in a way as to counteract, or at least compensate, for the potential for brain drain to undermine efforts to develop local scientific capacity in developing countries. Interviewees noted that many developing countries have also been making investments in scientific research infrastructure to both train and retain their scientists. Brazil and China were mentioned repeatedly as particularly strong examples of emerging economies that are excelling in this respect through increasing salaries of scientists and funding the creation of word-class research laboratories.

Finally, several interviewees highlighted the importance of cross-pollination of capacity, i.e., researchers from the North working for extended periods in the South, as opposed to “parachuting” in for a few days or weeks to conduct research and then quickly leaving. Many argued that the traditional scientific metric of peer-reviewed publications does not incentivize developed country scientists to devote the substantial amount of time needed to build capacity in developing countries. One described it as a system of “publish or perish”. This was distinguished from recognition within the medical profession, for example, where credit is given for setting up a hospital or clinic in developing countries. By analogy, one interviewee asked why scientists should not get credit beyond publications, say for helping set up a scientific laboratory in a developing country. The idea of South-South cooperation was identified as another possible response to the brain drain dilemma: emerging economy scientists could be encouraged and funded to help establish research laboratories in developing countries.

3.3.5.4 Data access and quality

The movement toward open access to climate data in the developing world has been laborious and remains a distant dream. There was consensus among interviewees that obstacles to data access are a major impediment to enhancing scientific capacity to address climate change in the developing world. Numerous interviewees highlighted the problem of access to historical climate data in many developing countries. Additionally, an IPCC survey found that data availability was the dominant concern in most developing countries, more so than computational capacity, which nevertheless was still a notable challenge that was reported (IPCC, 2009).[11] Underfunded national meteorological services in these countries have, in many cases, insisted on selling access to this data, making it more costly for developing country scientists to secure the most basic information needed for their work. In Brazil, litigation resulted in scientists finally being given access to such data through a password-protected website, according to one interviewee.

Control of climate data has been the norm in some developing countries because such data was historically collected around airports by national militaries, which do not have a tradition of openness and transparency, or was otherwise viewed as confidential. One interviewee explained: “A lot of countries see it as a threat to provide inside information.” In other instances, the problem of data access is more technical in nature because such data was recorded in handwriting in paper-based ledgers that would be costly to digitize. Data storage, rescue and archiving are particular problems that were also noted, particularly with respect to Small Island Nations in the Asia-Pacific region. A lack of international standards for climate data is also problematic since it can frustrate working with, and comparing, data from multiple countries. As one interviewee noted: “How do we know that data is of real quality, standardized? … I think it is coming into its own now, but what about all the historical data, how do you manipulate it? The meta-data needs some standardization.” In short, the reasons for poor data access identified by interviewees are myriad, and vary from country to country in the developing world.

Even when climate data is accessible, data quality is a major concern in developing countries due to deteriorating or inadequate infrastructure for capturing climate data in a reliable and consistent manner. National budgets in developing countries rarely prioritize

[11] For its part, the IPCC has created a Data Distribution Centre to provide data to researchers, government, and non-governmental organizations that is relevant to climate research (e.g. climate and environmental data as well as socio-economic data) (IPCC, 2009).

climate data collection and some international efforts to create regional climate data collection infrastructure have suffered due to a lack of funding to maintain such monitoring networks. Even basic data collection may be prohibitively expensive for many countries. As one interviewee explained: "[c]limate in the ocean requires oceanic information and equipment that is very expensive to run, operate, and maintain." The same interviewee also explained that the scientific equipment needed to make regular atmospheric sounding measurements to measure climate, which must send data several times a day, is expensive and "in many developing countries beyond the reach of the [metrological] service."

The causes of poor data quality in developing countries are often, however, more complex than inadequate funding. As one interviewee noted, for "the detection of climate change – you need long-time series of climate variables." As such, the very nature of climate data makes it vulnerable to interruptions in data collection. In developing countries, "interruptions in government, in funding, civil distress, often result in interruption of data collection to understand the environment. This is a serious issue for Africa, where most countries have irregular gaps and dubious quality or unknown quality of information in their records."

Another problem with ensuring high data quality is cultural in nature, in terms of a general lack of a tradition of questioning the reliability of data in specific instances where questionable data exists, not wanting to embarrass or offend those who are presenting the data (i.e. saving face). Interviewees noted that while developing country scientists are often aware of the issue of uncertainties, "[b]ut the sophistication behind that, one would probably need more capacity". A lack of "background" prevented such developing country scientists from "thinking about precision that was very sophisticated". Due to the global nature of the IPCC's work, they have taken steps to address this with their authors by including such topics: "In some situations, people from developing countries may be reluctant to ask a question, culturally it may be challenging. For example, how to treat uncertainties in the document. There's a small group session on that so we make time for people to understand it."

The consequences of inadequate data access and poor data quality are significant. As one interviewee stated: "The fact that some data is simply lacking in certain countries, particularly in developing countries is a problem because it prevents a thorough analysis of the impacts of climate change in those areas. Without a good information basis and analysis, it is very difficult to say something about what could happen in the future and how to manage and prevent it."

As more data is slowly being made available to developing country scientists, however, the results are promising. According to one interviewee: "the protocols to get data are simple and user friendly. The use of data is increasing, this is bridging the gap between new knowledge production. The South is producing more papers on climate change: ten years ago it was 10% of papers, today it is over 20%. Data accessibility is a big part of this. However, the fundamental problem of accessing climate data in the South is still there." Developing countries have reported to the IPCC that "there is insufficient literature regarding climate change in their country" and expressed concern that so-called "grey literature" (i.e. governmental and non-governmental reports) from their countries was not being used enough (IPCC, 2009).

3.3.5.5 Technology and research resources

Once developing country scientists have access to reliable climate data, there are other factors that limit their ability to use that data to produce and disseminate knowledge. One interviewee described the range of impediments facing developing country scientists as follows: "Their challenges are around doing analysis, training in particular statistical techniques, access to statistical databases, download speeds if you need to report to people, access to scientific literature (anything that's not open access). On the other hand, the open access journals are charging $2,000 to $5,000 to publish in them, so it is a challenge for people in developing countries to publish in them."

Technology, and the access to technology, to process and analyze climate data is a precondition for this scientific work. Many interviewees agreed that sophisticated climate modeling (such as down-scaling climate models to the local level, as discussed below) requires super-computers that are beyond the current capabilities of most developing countries. For example, the Brazilian Climate Research Unit has super-computer capabilities to do advanced climate science and is collaborating with other countries in the region. One interviewee described many climate topics and domains including general circulation models (GCMs), climate data, adaptation, resilience and mitigation as "technology rich", adding that "more complex technologies take more infrastructure, education, the pyramid base must be much broader to handle the sophistication, especially in climate science proper."

Telecommunication bandwidth to transmit and receive data and access online resources such as research publications is also a challenge in many developing countries, where cellular technology is the leading means of communications and hardline network connections through telephone lines are non-existent. One interviewee described the situation in developing countries saying "We don't have anything comparable in our academic institutions [in the North], … simple problems like having too narrow a bandwidth to download documents. Some of the scientists [in developing countries] would be at Internet cafes to find higher bandwidth to download the publications." Such limitations are becoming increasingly important as more scientific resources, including such climate forecasting programs as NOAA's Climate Predictability Tool, move towards "a web environment instead of a PC environment".

3.3.5.6 Downscaling / up-scaling

Looking back, one interviewee observed that historically "[t]here has always been high interest in regional modeling", noting that "[o]ne of the first requests from many countries was for regional models, for better understanding of changes in temperature and precipitation in their own countries." And because of this focus, "[t]here are now large scale programs that are international, to do regional modeling".

"Downscaling" global or regional climate models to the local level was viewed by several interviewees as important for advancing local adaptive capacity in developing countries that are vulnerable to the most serious effects of climate change. However, such analysis requires access to super-computers that are not available in most developing countries, as noted above. Downscaling appears to be useful when applied to straightforward cases, however several interviewees expressed concerns about the usefulness of downscaling based on existing technology because of the complexity of local geographical and physical features. One interviewee stated: “when you begin to downscale climate models, the uncertainty increases massively to that point that you might as well be throwing darts into the side of a barn.” Another was also skeptical that downscaling could “provide the kind of information that decision-makers and societies will require in order to make useable decisions.”

On the other hand, “up-scaling”, bringing forward local knowledge and adaptation strategies, was described by one interviewee as an advantageous approach to helping share strategies being successfully used in one community that may be “translated” to other communities. As one interviewee stated:

> “knowledge may be effective within the [low income] country but not effectively communicated outside the country in a way that facilitates better understanding of impacts and potential responses. It is important to have collaboration so that people learn lessons from each other, and that different groups don’t have to learn the same lessons over and over again.”

Some interviewees mentioned capacity building initiatives that bring developing country scientists and local traditional knowledge together as a possible way forward to localize climate models in these countries. One interviewee explained a situation “when the climate modellers sit down with these guys [the local indigenous knowledge practitioners], these guys are so familiar with local features that affect weather patterns that the guys from the climate modelling community say ‘we think this is going to happen’, and the local guys will say ‘but we have a lake, and that lake always prevents these cold fronts from moving in. In this village, it is always a few degrees higher.’ They’re able to add specificity to the downscaling.”

3.3.5.7 Interdisciplinary nature of climate change

There was consensus among interviewees that the complex nature of the climate change problem requires a new type of response "across disciplines, institutions, and international boundaries." There is an emerging recognition of the need for "multi-disciplinary" and "trans-disciplinary" research, involving such disciplines as social sciences, economics, law, statistics, physical sciences, biology, and so on. As a result, "the next generation of experts" must be grounded in solid disciplinary science, but also must possess "a good ability to dialogue with other disciplines" and must be equipped to engage in interdisciplinary research with a regional emphasis. However, this widespread acknowledgement of the need for an interdisciplinary cadre of scientists has not been integrated in most developing countries, where the traditional disciplinary model is "more pronounced" than in developed countries.

Most universities in developing countries continue to follow a traditional model where departments and faculties are "silos" of knowledge, with little interdisciplinary education and research opportunities. Many universities were established before such large and complex knowledge domains as "global environmental change" or "earth-system science" existed, which consider the intricate interactions between the physical aspects of the planet, the biosphere, the geo-chemistry of the land, oceans and atmosphere as well as social, economic, and other human systems. Many current leading scientists were trained in the 1970s and 1980s when the focus of research was on "specific disciplines and highly specialized topics." As one senior scientist put it: "[t]he type of question, the type of research that is required today to span the problems that we're facing are fundamentally and significantly different from the way, for example, from [how] my Ph.D. dissertation [was done]." Another interviewee explained: "addressing global change is a hugely interdisciplinary and inter-sectoral effort that hasn't really existed in that form in any other way in the past."

Beyond formal education, there was a recognized need among interviewees for research funding opportunities, scientific journals, and professional societies to encourage interdisciplinarity. Interviewees acknowledged that this may be a lengthy process, with one mentioning: "It took quite a lot of time where there has been a shift in Europe, in Canada, to interdisciplinary learning." Unfortunately, "[i]n the majority of countries in Africa, that is not happening. So the capacity is not as strong to deal with interdisciplinary research." As a result of this inadequate pursuit of interdisciplinarity, developing countries are thus generally less prepared to address the climate change problem.

3.3.5.8 Science-policy interface

Effectively addressing climate change requires the translation of scientific knowledge for policy and decision-makers. However, traditional scientific publications are "not the way knowledge is transmitted to society or the policy sector" and thus it was widely recognized by interviewees that scientists must also have the necessary skills to interface with these lay users of climate change research. While there is still a need for predictive climate models, the emphasis has shifted in recent years to vulnerability, impacts, adaptation, and mitigation – all of which are deeply interwoven with policy implications. The need to bridge the science-policy divide is "very sector specific and regional in nature", and therefore necessitates the involvement of developing country scientists.

Science-policy interactions also possess an interdisciplinary angle. As one interviewee noted: "[t]hat extra step to take the science and connect it with the needs of society requires cooperation and coordination from multiple disciplines." There was recognition that because of this reality "the nature of science is changing and therefore the way that we organize ourselves to do the science, on one hand, and facilitate its interpretation in a way that is useful to these wide ranging group of users is drastically changing".

The issue of academic merit within institutions was again raised here, with one interviewee explaining:

> "One of the problems with making [climate] information available to the public or policy sector is that scientists work as scientists, to publish in scientific journals. They get their incentives all based on simple counts

> of scientific peer-reviewed articles. That is not the way knowledge is transmitted to society or the policy sector. They have very few incentives to do that kind of work. Very often they're not trained to do it. We're missing in the science funding world mechanisms to encourage that sort of communication and provide funding for intermediaries for translators, if you wish, for that sort of information into the policy sector."

Another issue that arose was the time lag between research and policy. As one researcher noted: "Oftentimes what happens is you're so busy trying to meet a specific need, by the time you get papers out there and science has addressed the policy, the decisions have already been made about the policy." Scientists must make difficult decisions about their precious time and resources, claiming that "we're no longer on the cutting edge because we're addressing specific policy needs, to get ahead of the game."

Still, interviewees believed that a shift towards a policy-literate scientific community was much more advanced in developed versus developing countries. Yet, progress is being made, especially in areas of pressing concern. One interviewee noted that with policy personnel in developing countries, "[w]here you find the greatest level of knowledge is on the vulnerabilities and impacts: what it might mean for jobs, for security, populations near a coast."

Several interviewees cited the IPCC is an example of a major effort to interpret scientific research in a way that is useful for policy and decision-makers. As mentioned in the introduction to this paper, unfortunately developing country scientists have not been proportionately represented in the IPCC process as participants.

3.3.5.9 Language, culture, and gender issues

Addressing climate change effectively requires the translation of scientific knowledge for users of that information in a responsive and respectful manner. Working as a global community of climate scientists can present barriers to effective knowledge translation and use. As one interviewee described it: “when you’re developing capacity, … you can’t really do anything at the national level, it really needs to be sub-regional, or cross-border. Cultural distances are a huge problem. You need to be aware of cultural sensitivities.” A particular difficulty was noted in working with indigenous communities, where “chang[ing] mindsets and develop[ing] capacity for sustainable development is incredibly difficult.”

One challenge often mentioned was the limitation of language. As one interviewee explained: “To develop capacity, you can’t just jump in with English and expect everyone to understand.” To overcome this, some organizations conducted capacity building workshops on the ground and in communities in local languages. An IPCC survey found that the majority of countries would prefer to see more effort put into translation of key texts into official UN languages, beyond English (IPCC, 2009) to help reach stakeholders and conduct outreach activities. One organization reported using alternative strategies to raise awareness of climate change, particularly sea level rise, in a culturally sensitive manner. Local teams used youth and drama shows to preclude participatory workshops, which involved participants renditions of environmental change before carefully bringing in technical aspects. They reported that this approach “seemed to have a huge impact on the communities involved.” At a global level, some IPCC author groups have been enlisted to develop multi-lingual libraries to support developing country scientists to be fully engaged in IPCC assessments, having them “identify publications or government reports in the local language, that would be harder to find.”

Within climate science there is a growing focus on gender, “looking at how men and women are potentially vulnerable in different ways and have different capacities to adapt” to climate change, and then integrating this information into capacity building projects. Some organizations have explored gender dimensions of climate vulnerability and adaptation through workshops and learning forums. Other marginalized and socially vulnerable groups including youth were also mentioned for inclusion. Other organizations are making efforts to balance participation between genders during trainings and workshops. Although it may be an issue, no interviewees explicitly mentioned gender inequities within scientist and academic groups.

3.3.6 Capacity building models

3.3.6.1 From a traditional to a holistic approach

At this stage of analysis, it is apparent that there are substantial limitations and barriers facing any long-term effort to meaningfully enhance the scientific capacity of developing countries to effectively respond to the challenge of climate change. The reality of scarce resources at the international level to ameliorate this situation, which is only likely to face further strain given the ongoing global financial crisis, means that a more effective approach must be identified and deployed to have the maximum impact in terms of enhancing the scientific capacity of these countries that are the most vulnerable to the impacts of climate change.

The current approach taken by international institutions to building scientific capacity could generally be described, with some limited but notable exceptions, as traditionalist as opposed to holistic. A 2003 study (Horton et al.) that was sponsored by the IDRC and the Netherlands-based International Service for National Agricultural Research (ISNAR) and ACP-EU Technical Centre for Agricultural and Rural Cooperation identified capacity building for development as taking place at the individual and project team level (micro), organizational level (meso), and national institutions (macro). The study concluded that a piecemeal or "traditional approach" to capacity building that is driven by external donors and targets various individuals, projects, units, or organizations without an overarching strategy has been found to be ineffective in other development contexts. Instead, what is favoured is a more "holistic approach" to capacity building that begins with identifying needs and then draws on relevant external resources to comprehensively build long-term capacity. In other words, rather than the priorities and programs of donor organizations driving the capacity building agenda, a more responsive approach is required.

Interviewees repeated again and again the realization that individual capacity building programs would be ineffective if they were not combined either with necessary preconditions or conducted in concert with other capacity building projects. For example, a graduate scholarship program may succeed in helping a young developing country scientist obtain a Ph.D., but without a scientific institution to recruit and retain that scientist in their home country, they will be led to seek work abroad (i.e. “brain drain”). Likewise, a generous funding envelope for proposals for collaborative research will not be open to developing country scientists that lack the institutional support and capacity to effectively manage and administer the grant money. A regional scientific network on climate change will be unable to function effectively to contribute to global climate science and policy without a cadre of scientists in the region who are experienced in addressing interdisciplinarity and the science-policy interface. It was thus clear to most interviewees that the various projects and programs that are being undertaken are not competing or alternative capacity building approaches (i.e. the traditionalist approach to capacity building), but rather are complimentary and are in fact interdependent on one another for their ultimate success (i.e. a holistic approach to capacity building).

Only one of the seventeen international organizations included in this study (IDRC) was found to be operating, at least to some degree, at all five programmatic levels for scientific capacity building related to climate change (i.e. graduate scholarships and post-doctoral fellowships, trainings and workshops, collaborative research, organizational support, and networks). Even with the IDRC, these programs were geographically limited to Africa and were not all operating at the same or in a coordinated fashion. Indeed, most if not all, of the organizations active in scientific capacity building for climate change in the developing world have engaged in regular partnerships with other organizations to either expand their geographic scope or implement more in-depth projects on a regional scale. It was conceded by many organizations that if an individual were to simply attend a 2-day training workshop on a specific topic related to climate change that it would not have any meaningful long-term effect on either the individual or their country. Instead, one interviewee described how their organization attempted to integrate a range of capacity building strategies together to amplify their effect as follows:

> “In a couple of cases, we’ve paired up [a] training event with a seed grant opportunity. People at the event were given the chance right there

> and then to write a proposal for taking the training back home, or by linking some of the participants to one of our science projects. These were in the $8000 to $15,000 range. Then we would have a real tool to see if these people could write a proposal that is fundable. Also, we keep seeing people from these training events pop up in the research teams later on. We give them an opportunity to grow into the science networks. The original periods of establishing the science programs began with startup grants, usually trainings and meetings. Then the science grants of a couple thousand allow people to find their feet. Then the collaborative grant of a million dollars. These were open calls, but the people who had gone through the steps knew how to build networks. We try to build this up in steps, so that capacity building can lead to some of the bigger grants."

This idea of a holistic and integrated approach that regards scientific capacity building as a multi-level process is a powerful concept that warrants further development, as described next.

3.3.6.2 The holarchy: a holistic approach to scientific capacity building

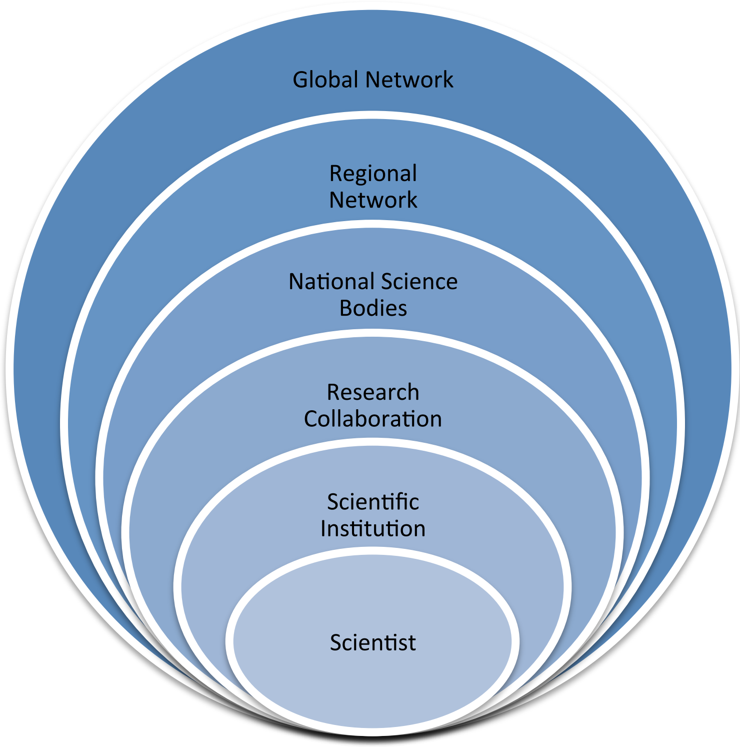
Capacity building to address climate change is a multi-level system. The study mentioned above by Horton et al. (2003) introduced the idea that there is a need to holistically conceive of capacity building, with the individual at its core. Beyond the individual was a project team, organization, and national institutions. While this study is based on the astute understanding that capacity building must take place at multiple levels in order to be effective, it is neither tailored to scientific capacity to address climate change (i.e. it is limited to a national context), nor does it provide a deep enough understanding of *how* capacity is built and should be evaluated.

There is a body of literature on theories of organizational change that also deals with complex multi-level systems that has some fascinating potential applications to understanding the challenge of scientific capacity to address climate change. The work began with Arthur Koestler's influential 1967 book that introduced the idea of the "holon" to help understand change in multi-level systems. It has been since developed and applied in a number of different fields. An "integrated holon" depicts the levels involved in a workplace application of the theory in a common business environment and the relations between the levels.[12]

Figure 3.1 proposes an application of this holarcic approach to global capacity building to address climate change. It recognizes that to have effective global, regional, national, and local scientific capacity in countries around the world, there are multiple levels that must all effectively function. It also recognizes that these levels are directly linked to each other, but also that in order to function to the next higher level on a long-term basis, it is necessary that each of the levels below be well established. The concept is based on holarcic theory, which is an understanding of *systems* (which is how capacity building has been understood in this study) which recognizes that there are various levels or subsystems: "the different holarcic system levels consists of each other, they are subsystems (or supersystems) to each other" (Edwards, 2005; Günther, 2006). If a gap exists at one of the holarcic levels, then it will prevent the next level from being formed. In other words, the lower levels are the building blocks for the higher levels. For example, insufficient national science bodies (i.e. IPCC focal points, national science academies, etc.) will prevent sufficient numbers of developing country scientists in those countries from being identified for participation in regional and global networks.

[12] Interestingly, one of the authors of the Horton study (2003) on organizational capacity development was evidently acquainted with Koestler's theory (albeit without citing it) since they used the micro, meso, and macro labels in their basic figure to describe the levels of capacity building they envisaged.

Figure 3.1 A holarcic framework for capacity building to address climate change



Interestingly, the various approaches identified in this study operate at different levels of this holarcic framework. Graduate scholarship and post-doctoral fellowships are designed to nurture the first level of this integrated holon (i.e. the individual scientist). Organizational support aims to cultivate "centres of excellence" in research in developing countries at the second level (i.e. scientific institution). These institutions provide a home and base for individual scientists to work from. Collaborative research programs foster the generation and use of scientific knowledge and are integral to interdisciplinary climate science work at the third level. There were only limited programs identified to foster national science bodies (i.e. IPCC focal points, national science academies, and national science committees) at the fourth level to provide an interface between a country's scientists and regional and global networks. Regional networks, such as through START, APN, IAI, AfricaAdapt, and AfricaNESS, were popular and supported programs identified in this study. Finally, the global networking of scientists (including the IPCC) was facilitated through the regional networks and national scientific bodies. In other words, each level builds on each other and is vital to the one above. Seen in this light, the various capacity building activities identified in this study are not competing, but have a direct relationship with each other and will be most effective if they are pursued in a strategic and integrated manner.

The additional strength of this holarcic vision of capacity building for climate change is that it offers a clear answer to how to *prioritize* and *evaluate* capacity building initiatives. First, a national scientific capacity needs assessment can be undertaken to identify in objective terms which levels of the holon are either non-existent or insufficient in the country and should thus be the focus on capacity building efforts. For example, Developing Country "A" may lack a university with a graduate program in climate science but have an internationally funded centre for research excellence. Such a centre would find itself having to hire scientists from outside of the country and suffer from a lack of participation from local scientists. In such a country, the focus for capacity building activities would be organizational support for the major universities in that country to develop a graduate program (rather than funding a handful of students from that country to seek graduate degrees abroad, thus contributing in all likelihood to "brain drain"). On the other hand, Developing Country "B" may have a university with a climate science program at the graduate level and be producing such graduates. Such a university may also have a reasonable level of support for research and encourage participation in collaborative research. However, a poorly administered IPCC national focal point in that country may be failing to identify appropriate scientists for nomination to participate in the next IPCC assessment report – a process that would benefit both the individual scientist and their country. Indeed, it is no wonder that developing country scientists affiliated with institutions in developing countries are so poorly represented in the IPCC assessment reports – in order for them to do so, they must first have qualified graduate education, be affiliated with a respected scientific institution, have a track record of collaborative research, and have been identified by their IPCC national focal point. If any of these critical levels is deficient, then it makes it highly unlikely that scientists from such a country will be able to succeed in being nominated and selected for participating in the IPCC.

The second major advantage of viewing capacity building through this holarcic model is that it offers a ready metric for evaluating capacity building efforts that is not merely a "proxy" for capacity building. The real test of capacity building activities under this framework is whether they are sufficiently robust and successful enough to enable the capacity building subject to move up to the next level above the targeted level of programming. For example, if the specific program was to fund and support a climate science research laboratory in a developing country, the measure of success of that laboratory from a capacity building perspective would be the extent to which that laboratory was active in collaborative research projects and regional networks. Likewise, a program that funded graduate students to obtain their advanced scientific degrees would be measured based on the success rates of those beneficiaries in securing employment as scientific researchers in various institutions.

3.4 Conclusion

Building scientific capacity in developing countries to address climate change is now widely accepted within the field as necessary and a range of international organizations have mobilized funding and other resources to that end. Unfortunately, despite several promising programs, their limited scope and scale, combined with a largely ad hoc approach means these limited resources are not being used to maximum effect. In short, despite the gravity of the climate change problem facing developing countries, we currently lack a concerted global effort to build scientific capacity in the developing world.

As one interviewee said, a "revolutionary" approach is instead needed. Such an approach would have donor and implementing organizations work collaboratively with each other, developing countries, and intended beneficiaries to first identify the specific needs for capacity building as they are tailored to each country, and then secondly to focus capacity building efforts to meet those targeted needs. Given that capacity building is a dynamic and iterative process, periodic assessments followed by targeted action should continue so that each country is able to progressively build up each level of capacity from the individual scientist, to institutions for scientific research and policy, to supporting collaborative research, to national science bodies and national science academies, to regional networks to active participation in global networks. Donor funding and prioritization needs to be responsive to the particular needs of developing countries in each of these areas.

Fortunately, some of the tools for a more comprehensive, coordinated, and strategic approach to capacity building in developing countries to address climate change are already in place, from national self-capacity assessment (NSCA) tools to well-developed individual programs. There also exist functional regional networks in the Asia-Pacific and the Americas, with recent attempts to try again to foster a regional climate science network in Africa. There are also signs of success in larger collaborative projects involving multiple donors that integrate multiple capacity building strategies in a single region or targeted set of countries, such as the ACCCA, AIACC, and CCAA projects. While each of these major projects have ended, they are compelling examples of what can be achieved if a more strategic and integrated approach to capacity development can be achieved in terms of fostering and mobilizing local scientific capacity in developing countries to address climate change.

Climate change represents a serious global threat to our way of life, and nowhere is this more of a concern than in developing countries. It is essential that well meaning programs and resources be more effectively deployed to enable those facing the most severe impacts of climate change to be as prepared as they can to adapt and mitigate the effects of this challenge.

4. Conclusion

4.1 Summary

There are three high-level findings that have emerged from the quantitative and qualitative analysis in this thesis. While the first two of these findings give cause for serious concern, the third raises some sign of hope:

1. Developing country scientists and institutions remain grossly under-represented in global climate science, despite acknowledgement of this problem and efforts to address it.

2. A decade after the international community committed to building scientific capacity in developing countries to address climate change, despite limited but notable exceptions, the response has been inadequate and deficient to meet this challenge (i.e. the programs are time-limited, not integrated with one another generally, and lack broad geographic scope and coordination).

3. A comprehensive, integrated, and strategic approach to coordinating the efforts of international institutions seeking to build scientific capacity in developing countries would ensure that the impact of their efforts is amplified such that their concerted action will be much greater than merely the sum of their individual initiatives.

More specifically, in Chapter 2, it was determined that 45% of countries, all Non-Annex 1 (i.e. developing countries), have *never* had authors participate in the first four IPCC assessment reports; on the other hand, European and North American experts make up more than 75% of all authors (N = 4394). Generalized linear models using negative binomial regression were used to quantitatively estimate the effect of a number of socio-economic, environmental and procedural factors influencing country-level participation in the IPCC. Per capita gross domestic product, population, English-speaking status, and levels of tertiary education were all found to be statistically significant drivers of authorship counts. In particular, participation by authors from English-speaking Non-Annex 1 countries is 2.5 times greater than those that are non-English speaking. Regionally, small island nations of Oceania were the most severely under-represented group. South American and Asian countries had fewer authors, and African countries had more authors than what might be expected on the basis of demographic and socio-economic data. These differences across nations partly reflect existing scientific capacity that will be slow to change. However, the on-going under-representation of developing country scientists in the IPCC, particularly in the assessment of climate science (WGI) and climate mitigation (WGIII) warrants greater efforts to close the capacity gap.

Existing efforts to build scientific capacity to address climate change were highlighted and conceptualized in Chapter 3. While several impressive integrated capacity building initiatives were identified in this study operating at the regional level, most capacity building activity was found to be isolated initiatives at the individual program level, including: graduate scholarships and post-doctoral fellowships, trainings and workshops, research collaboration, organizational support, and regional and global networks. This chapter also identified a number of significant obstacles to achieving sustainable, long-term scientific capacity to address climate change in developing countries. Foremost of concern were limited funds and other financial constraints combined with insufficient climate science institutions in developing countries. Other challenges included the "brain drain" phenomenon, data access and quality, technology and research resource limitations, difficulties with downscaling/up-scaling of climate modeling, the interdisciplinary nature of climate change, navigating the science-policy interface, and issues related to operating across culture, language, and gender. Finally, it was concluded that the largely ad hoc approach to individual capacity building activities should give way to a more comprehensive, integrated, strategic approach to building scientific capacity in the developing world. Exemplary initiatives are identified as examples of such an approach that should inform governmental, non-governmental, and donor involvement and support for capacity building activities to ensure a more effective response.

4.2 Strengths and limitations of the research

The strength of this study is two-fold. First, it confirms through quantitative analysis that the problem of under-representation of developing country scientists in the IPCC is not only proven, but also that it is not substantially improving over time. The outright exclusion of any authors affiliated with institutions in a very significant proportion of developing countries is alarming and persistent. This study has confirmed the suspicions and fears that have been raised historically through largely anecdotal and qualitative evidence that such under-representation has been apparent to many engaged in climate science for years. It has also confirmed that the problem of under-representation of developing countries in the IPCC that was first quantified by Kandlikar and Sagar (1999) has persisted to the present day. Moreover, this study has found a significant language barrier existing that provides evidence of not overt, but systemic discrimination, such that developing countries that are non-English speaking are even less likely to be included in the IPCC process. Secondly, the study offers the first comprehensive look at the state of international capacity building efforts related to developing country scientists to address climate change. The comparative approach that combined both open source and interview data provides a rich and thorough examination of this topic that is growing in importance.

There are several limitations to the study that have been previously noted, but warrant revisiting. First, participation in the IPCC is but one measure of the participation of developing country scientists in global climate science. Considering other measures such as publication records and impact, grants, positions on research and editorial boards, and senior appointments would provide a more complete perspective on the general question of how engaged developing country scientists are in global climate science. Additionally, it was noted in Chapter 2 that the IPCC only identifies authors by their current academic affiliation and that developing country scientists are likely to be under-reported because many are believed to be appointed at institutions in developed countries. While this is a limitation, it should not be over-stated. Developing country scientists who are primarily appointed at developed country institutions may be considered to be affected by the "brain drain" phenomenon and are less likely to be engaged in local climate science, adaptation, and mitigation in their home countries. Additionally, the fact remains that the

IPPC tracks institutional affiliation, and developing country institutions are starkly underrepresented.

Secondly, the capacity building programs that were identified, analyzed, and evaluated in this study are not exhaustive. While significant efforts were undertaken to identify the most significant programs, it cannot be said that the study has encompassed all relevant programs. Nevertheless, there is a high degree of confidence that most of the major capacity building programs directed at developing country scientists to address climate change have been included due to the methodology employed (i.e. both open source and interview data). A related limitation is that only programs that were specifically related to scientific capacity related to climate change were included. There are other general capacity building programs related to higher education or scientific research that were not included in the study. Such non-specialized programs will indeed have an indirect impact on scientific capacity to address climate change, but were not included due to their focus being more generic and broad. Nevertheless, the findings from the study could inform such activities as elaborated below.

A final limitation that warrants mentioning is with respect to interviews being conducted primarily by telephone. It is understood that face-to-face interactions are preferred for semi-structured interviews to build rapport and enhance disclosure (Wengraf, 2001; Cohen, 2006), however this was not possible due to the global distribution of interviewees. Nevertheless, interviewees were very forthcoming and often volunteered information that was both positive and negative about their own organization's work, suggesting they understood and respected the interview protocols established to facilitate a frank and open exchange of information.

4.3 Potential applications of the research findings

There are a number of potential applications of the research findings. Firstly, the IPCC will face additional pressure to take more significant steps to include developing country scientists in its assessment reports moving forward, as its existing approaches in doing so have stalled. Cultivating national focal points to identify developing country scientists, in closer collaboration with a wide range of organizations involved in capacity building of developing country scientists, is one approach that could be undertaken with greater rigor by the IPCC. Additionally, the published version of Chapter 2 has already been cited by another study and applied to call into question the exclusion from the IPCC other key marginalized groups vulnerable to the most serious impacts of climate change, namely indigenous populations (Ford et al., 2011).

Secondly, the organizations involved in delivering capacity building programs all expressed an interest in obtaining the results of this study during their interviews. There was widespread interest among organizations involved in building capacity of developing country scientists to address climate change in how such programs in particular should be prioritized, funded, and evaluated. The scarce resources available for capacity building in this area need to be better deployed for maximum impact, and the call made by this study for a needs-based and more holistic approach could be of tremendous value to donor and implementing organizations.

Thirdly, the research findings will also be of interest to developing countries, in particular their national focal points and climate science institutions. A needs-based approach that is informed by the local conditions and priorities of individual countries was validated in this study. It should make donors more aware of the need for such a bottom-up approach, and grant recipients less willing to simply "follow the grant money", but instead advocate for targeted funding and programs that will meet the most pressing gaps in national scientific capacity to address climate change. Climate negotiators from developing countries will also see the study as validating many of their equity concerns and a confirmation that existing efforts to build scientific capacity are inadequate.

4.4 Directions for future research

This study has the potential to contribute to a broader understanding of capacity building in complex issues that involve interdisciplinary problems. The holistic and multi-faceted approach to capacity building, described in Chapter 3, could be examined, tested, and improved on in other contexts.

It became apparent during this study that the general “lessons learned” from other fields where capacity building has been pursued for a longer period of time have not been incorporated into all of the initiatives being undertaken to improve scientific capacity to address climate change. For example: “Notably, country ownership and endogenous process of change are essential principles when defining capacity development initiatives. Beneficiaries need to also be supported to ‘define their own needs and shape their learning process’ … Capacity development needs to be framed within the context of national politics, institutional arrangements, culture, tradition and historical backdrops. It is inextricably linked with power relations, competition and levels and types of control over resources exerted by different stakeholders” (Wickham et al., 2009).

Finally, this study has laid the foundation for the next stage of this research project that is being pursued by Professor Milind Kandlikar and Professor Hisham Zerriffi that will drill down further into the capacity building programs identified in this study. A survey of beneficiaries of these programs will be undertaken as part of a post-doctoral research position with cooperation from many of the organizations included in this study to attempt to more precisely measure the impact and limitations of those initiatives.

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Appendix: Interview Questionnaire

OVERALL ISSUE

1. Is building capacity for climate change necessary? If so, why?
    - *Impact on lives and livelihoods*[13]
    - *Equity, fairness*
    - *Who should be targeted for capacity building efforts?*

2. What aspects of climate change are the most in need of capacity building assistance?
    - *Climate science*
    - *Modeling*
    - *Data management*
    - *Impacts/adaptation*
    - *Inventories/CDM*

3. What are the most significant barriers or factors that limit capacity building for climate change in the developing world?
    - *Knowledge production, translation, use, feedback*
    - *Financial*
    - *Institutional*
    - *Data (quality, availability, information exchange, coordination, consistency, time-scale)*
    - *Science/policy interface*
    - *Feedback between scientific and user communities*
    - *IT (physical hardware, software, data integration)*
    - *Local context (modifying existing technology, appropriate incentives, local expertise)*
    - *Demand for appropriate information and appropriate methods/tools*
    - *Education (higher education programs in relevant fields and research infrastructure)*
    - *Current needs vs. future needs*
    - *Multi-disciplinary nature (physical, biological, social science)*
    - *Efficacy of co-production (is it happening effectively?)*

WHY? – *GOALS & OBJECTIVES*

4. How are priorities for capacity building determined internationally?
    - *Capacity building agendas (local, problem-based vs. international)*

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[13] Italicized text refers to interview prompts that may be used to provide interviewees with an opportunity to delve more deeply into the primary question.

5. Is your organization engaged in capacity building? If so, what are the priorities and goals of your program(s)?
    - *What is the strategy your organization uses? What differentiates your approach from others?*

WHAT? – *BREADTH & SCOPE*

6. What aspects of capacity related to climate change does your organization address in its program(s)?
    - *Climate science*
    - *Modeling*
    - *Data management*
    - *Impacts/adaptation*
    - *Inventories/CDM*

7. What types of capacity building programs does your organization deliver?
    - *Institutional (training/workshops, advanced institutes for scientists)*
    - *Research (incorporating developing country scientists into research projects, cooperation on topics specific to region)*
    - *Mixed (fellowships, PhD funding)*

HOW, WHERE, WHEN? – PROGRAM *STRUCTURE*

8. Can you provide more details on the structure of your programs?
    - *What topics are covered as part of each program?*
    - *What materials are used in your trainings/workshops?*
    - *How is the material delivered?*
    - *Who are the instructors?*
    - *What is the duration of the program?*
    - *How long has your program been in operation?*

WHO? – *TARGETS*

9. To date, how many participants have been involved in your program(s)?
    - *What are their demographics, educational level and countries of origin?*
    - *Do participants participate in multiple programs at your organization or in similar programs with other organizations?*

10. What selection criteria do you use to choose participants?
    - *Experience/educational qualifications*
    - *Countries/regions of origin*
    - *Scientific domains of the participants (pure science vs. science-policy)*

11. How do most participants hear about your programs?
    - *How do you promote your program to prospective participants?*

HOW? – *FUNDING*

12. How is your program funded?
    - *Sources of core funding vs. program-specific vs. per participant*
    - *How much funding do you access on average each year?*

13. Are participants required to pay a fee to participate in your programs? If so, how much?
    - *Have any prospective participants been unable to secure funding to participate?*
    - *Are there any funding opportunities that your organization provides to those unable to pay the requisite fees?*

WHAT? – *OUTCOMES*

14. How do you measure whether your program has achieved its objectives?
    - *What skills do you hope to impart to participants through your programs?*
    - *What are the program evaluation criteria used and how well has your program met them?*
    - *What successes have you achieved through your program?*
    - *What type of follow-up mechanisms with past-participants do you use?*
    - *Impacts on careers of individual scientists vs. impacts on countries*

15. Have your capacity-building programs been formally evaluated, either internally, by donors or other external reviewers?

16. What are the main challenges/barriers your organization has encountered in implementing its capacity building programs? (both external and internal)

17. Are there any down-sides to capacity building for climate change?
    - *Brain-drain*
    - *Cost*

CONCLUDING QUESTIONS/COMMENTS

18. What recommendations would you have for strategies to enhance the capacity building activities for developing country scientists with respect to climate change science?

19. Are you aware of other programs/organizations engaged in capacity-building activities for developing country scientists with respect to climate change science? If so, can you provide further details on these programs?

20. Is there anything else that you would like to add about your organization's capacity-building programs?

21. Phase II of our study will involve surveys to be completed by participants in capacity-building activities for developing country scientists. Would your organization be willing to assist in distributing these surveys to past participants in your programs? We would be happy to provide more information.