Eradicating Blindness

Global Health Innovation from South Asia

Logan D. A. Williams

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Preface

In 2006, I discovered that my mother had early-stage cataracts in both eyes. At that time, we both lived in Boulder, Colorado, where I was a graduate research assistant in the Cardiovascular Dynamics and Ultrasound Laboratory. I decided that cataract disease (and the knowledges and technologies used to address it around the world) warranted closer scrutiny. In addition to my main research project on cardiovascular ultrasound, I completed a small secondary project at CU-Boulder on the bio-mechanics of porcine natural lenses. I also performed background research in February 2007 on the nature of cataract disease and was surprised by the great number of people it affects around the world. As part of this preliminary research, I checked out the World Health Organization's information about cataracts. On their website, they had a map that showed cataract surgical rates (or how many cataract surgeries per capita) for each country in the world in 2004. The fact that the USA, Western Europe, and Australia had high cataract surgical rates was not a surprise. What was confounding (to me) about this map was that it showed that India and Nepal also had high cataract surgical rates. *I had a puzzle: Why was it that India and Nepal had such high cataract surgery rates?* With my nascent interests in knowledge and technology transfer for a social purpose, I began to determine just why these two countries, which are not as economically developed as the USA, had comparable rates of surgery. After I entered the Science and Technology Studies post-graduate program at Rensselaer Polytechnic Institute, I conducted initial doctoral dissertation fieldwork at Tilganga Institute of Ophthalmology in Nepal in 2009. Thus by starting "at home" with my mother's cataract disease diagnosis, an interesting research project was born.

Cumberland, MD, USA Logan D. A. Williams

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I would like to thank God who answered my prayers with closed doors and open doors—guiding me all of this way on a path that I never could have imagined. I also very much appreciate the prayers and encouragement from my family and friends across the globe without which I would have been unable to finish this book!

Thanks are owed to all of the ophthalmologists, engineers, managers, and other individuals that I interviewed and observed in Kenya, Nepal, India, Mexico, and the USA. My fieldwork was facilitated by the introductions from various managers that I have been privileged to meet. For example, I am obliged to Thulasiraj Ravilla (India) for e-introducing me to Samson R. Ndegwa (Kenya); this introduction smoothed the way for my interviews at the Lions SightFirst Eye Hospital, Loresho (Kenya). Once I arrived at Loresho, Peter Ndigwa was kind enough to give me a tour of the campus, introduce me to potential interviewees, and organize my volunteer internship. I similarly appreciate Nabin K. Rai's coordination of my volunteer internships in the research department at Tilganga (Nepal) and Juan Carlos Rodriguez's work in arranging my interviews at Sala Uno (Mexico). My fieldwork in India would not have been possible without the invitation from Aurolab's P. Bala Krishnan to visit the Aravind Eye Care System. Thanks also to Thulasiraj for hosting me at the Lions Aravind Institute of Community Ophthalmology (India).

My homestay family in Kathmandu (God Bless you J, D, S, R, M and N!) and my colleagues at LAICO were generous in their welcome, especially: my officemate Sanil Joseph, his wife Anuja Sanil, and their daughter Sarah Sanil; Thulsi's daughter Dhivya Ramasamy; and Dhivya's officemate Sashipriya Karumanchi Munirathnam. Thanks to Shrilakshmi Kannan and Dhivya for introducing me to potential interviewees at the Aravind Eye Hospital, Madurai (India). I continue to have fond memories of: "Melody Fridays" and teaching the Research Seminar at LAICO.

Some of my interviews in the USA would not have been possible without the e-introductions provided by John Ciccione at the American Society for Cataract and Refractive Surgery, and Jenny E. Benjamin, the director of the American Academy of Ophthalmology Museum of Vision in San Francisco, CA.

I appreciate the comments of my colleagues (specifically Thomas S. Woodson, Mark Waddell, Denver Tang, Amit Prasad, Toluwalogo B. Odumosu, Dean Nieusma, Sharlissa Moore, Daniel Menchik, Les Levidow, Anna Lamprou, Abby Kinchy, Christopher Henke, Steve J. Gold, Sara Fingal, Kevin Elliott, Jubin Cheruvelil, Cliff Broman, Kean Birch, James Bergman, Rich Bellon, Javiera Barandiaran, and Atsushi Akera) on chapters as I revised my dissertation into this book manuscript. Dissertation comments from my mentor, Ron B. Eglash, made me more sensitive to the economic and organizational practices of non-profits. The work of my mentor, David J. Hess, on industrial transition movements, provoked the insight of dual socio-technical regimes that I develop in this book. I especially want to thank Sean Valles for his chapter-by-chapter comments—I can only hope that I did a good job of coherently and selectively incorporating these suggestions into the manuscript. I was significantly encouraged by those conference participants who commented on an early draft of Chapter 6 at "Science and Technology Studies in South Asia" in May 2010, especially my discussant Deboleena Roy.

Audra Wolfe at The Outside Reader and my first two anonymous referees showed me the potential of transforming an early draft of this book into something more interesting. Finally, I appreciate Linda Nathan at LogosWord Designs, LLC, for copyediting an early draft of the manuscript.

Collecting empirical data for this book was directly supported by: a Short-Term Travel to Collections Award from the Lemelson Center at the National Museum of American History–Smithsonian Institute; a Council of American Overseas Research Centers Multi-Country Fellowship; a National Science Foundation DDIG (No. 1153308); and a Rensselaer Polytechnic Institute HASS Fellowship. The data collection was indirectly supported by the Council of Women World Leaders Environmental Policy Fellowship. Any opinions, findings, and conclusions or recommendations expressed in this material are mine and do not necessarily reflect the views of any of the financial supporters.

Parts of this book, especially Chapters 1 and 2, draw from the following journal articles:

Williams, Logan D. A. 2013. "Three Models of Development: Community Ophthalmology NGOs and the Appropriate Technology Movement." *Perspectives on Global Development and Technology* 12 (4): 449–75.

Williams, Logan D. A. 2018. "The South Asian Origins of the Global Network to Eradicate Blindness: WHO, NGOs, and Decentralization." *Endeavour* 42 (1): 27–41.

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Introduction

On a Saturday afternoon in April 2011, an ophthalmologist speaking at the Unite for Sight Global Health and Innovation Conference described his observation of two eye clinics in the global south. During his slide show of photographs, he commented that the first Ghanaian eye clinic was "a one stop shop for eye disease" with a "systems approach" featuring two surgeons performing surgery simultaneously in the same surgical theater, a well-organized flow of patients, and the use of a microsurgical technique to correct blindness from cataract disease. A cataract is the clouding (opacity) of the eye's natural lens; like the mist from a waterfall, a cataract inside the eye obscures light and detail causing visual impairment or blindness.

I was already aware that the groundbreaking microsurgical technique developed at Tilganga Institute of Ophthalmology (Kathmandu, Nepal) results in very good patient outcomes despite the fact that expensive suture thread is not required to stitch the incision closed. Nor is this particular microsurgery disrupted by the rolling electricity blackouts that are frequent in some countries with overloaded electrical grids. As I listened, other parts of this systems approach were sharpening into focus: a radical aseptic technique to prevent pathogens from

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contaminating the surgical theater and unique labor-intensive logistical practices for the surgical theater. The speaker pointed out it was a "very efficient flow system that even by American standards is quite admirable." His comment, while appreciative, still manages to make the standards developed by ophthalmologists in the global south seem Other. He firmly places those clinics in a network of ophthalmologists broadly focused on population eye health. This network is subordinate as compared to the dominant network of ophthalmologists narrowly focused on individual eye health. His rhetoric also carefully delineated the boundaries between medical practices that are good for the global south versus what is good for the USA.

A live report from the 2010 Asia-Pacific Academy of Ophthalmology Congress in Beijing also emphasized the work of Aravind Eye Care System (Madurai, India) and Tilganga. This live report highlighted a growing scientific controversy in ophthalmology—the dispute between proponents of two different microsurgical techniques to restore eyesight clouded by cataract (Anonymous 2010). The incumbent microsurgical technique was made by an American ophthalmologist in New York City; the challenger microsurgical technique was made by a Nepalese ophthalmologist in Kathmandu. Before this September meeting, ophthalmologists, engineers, and managers at Aravind and Tilganga had spent many years creating South Asian eye healthcare institutions. These experts contested the definition of what true cataract blindness means in terms of visual acuity worldwide and helped to redefine blindness as a public health problem that is avoidable or preventable. Additionally, they performed the operations research, health education outreach, and community-building activities to make poor rural patients aware that blindness is often a preventable or solvable problem. They utilize evidence-based medicine to challenge the incumbent regime's cataract microsurgical technique because of its high cost. After they created the alternative microsurgical technique, they then performed the research necessary to validate this alternative technique as an appropriate option, both scientifically and economically viable, for poor patients.

Throughout this book, I will develop a theoretical framework for socio-technical transition called the dual regime thesis. In order to define this novel transition pathway, I will summarize existing literature on the multi-level perspective in transition studies, demonstrate the relationship of this literature to my case of community ophthalmology, and also develop the concepts of interlocking innovations, contestation, and systemic technology choice. In this book, I argue that community ophthalmology professionals are an example of systemic technology choice. Systemic technology choice illustrates a new shift in the global appropriate technology movement, where there is an emerging form of high-technology innovation that responds to the needs of low-income people. Unlike the previous appropriate technology movements, this new approach to development emphasizes systems thinking, where activists believe that technology transfer is the transfer of an appropriate system of artifacts, values, norms, and ideology.

The dual regimes emerge in part because of interlocking innovations: a novel constellation of context-appropriate processes or products in science, technology, and management connected to each other by a shared ideology. Interlocking innovations circulate through diffusion, appropriation, and translation to address problems of poverty in low-income countries. These interlocking innovations travel on a global stage to other less economically developed countries and even to the economic centers of the world economy. Finally, contestation explains how, in order to move from below, some actors use new forms of science and technology to challenge existing knowledge hierarchies and that this is a normal and productive part of scientific knowledge building and technology transfer. These concepts add a newer theorization of how knowledge and technology circulate as part of socio-technical system change to transition studies (Geels 2005; Smith et al. 2016), the political sociology of science (Hess et al. 2016), and feminist postcolonial science studies (Harding 2009; Pollock 2014).

In this chapter, I provide an overview of the goals of this book. The book's central argument is that the multi-level perspective in transition studies cannot be used to explain endogenous development of science and technology in the global south, unless we account for the occasional development of dual regimes. Endogenous development in this case includes a novel microsurgical technique used for high-volume, low-cost care for poor people in the global south that is supported by further innovations in surgical theater management techniques, low-cost technologies, and finance. This model is being successfully exported to other countries in the south.

The remainder of this introductory chapter has the following structure: Sect. 1.1 discusses the book's purpose to introduce South Asia as having multiple sites of low-cost innovation in the global field of ophthalmology; I describe connections between the problem of blindness, epistemology, and innovation from below. Next, Sect. 1.2 introduces the problem of avoidable blindness in more detail, including the startling facts that make this problem noteworthy; meanwhile, I also present the theoretical framework of multi-level perspective with socio-technical regimes. Scholars from science and technology studies, business, evolutionary economics, and, the government of the Netherlands, use this theoretical framework to think through science and technology adoption and governance issues (Geels 2002; Smith 2002). Section 1.3 describes the historical origins and current practitioner understanding of technology transfer, modern development, and appropriate technology in the global south. Next, Sect. 1.4 returns to the multi-level perspective and evaluates its limitations for understanding socio-technical change in the global south. Consequently, Sect. 1.5 introduces a new theoretical framework, the dual regime thesis, in more detail. Finally, Sect 1.6 concludes by summarizing Chapters 2–8.

1.1 Science, Technology, and Innovation from Below

The purpose of this book is to demonstrate how India and Nepal have emerged as sites of innovation in low-cost, high-volume cataract surgery. Cataract disease causes 51% of avoidable blindness worldwide, approximately 20 million out of a total of 39 million blind people (Pascolini and Mariotti 2012). This disease predominantly affects an older, low-income, and rural demographic (Pascolini and Mariotti 2012). While the causes are unknown, there is an increase in cataract incidence with age worldwide, where 1 in 5 people over the age of 55 years will have at least one eye with a cataractous lens (Pascolini and Mariotti 2012). The good news is that, in industrialized nations where prospective patients have regular access to eye health care, an outpatient surgical procedure can skillfully and quickly correct cataracts.

The bad news is that the infrastructure to address this problem in low-income rural communities around the world is largely absent. While significant gains have been made since the first efforts of rural ophthalmologists started in the early 1960s, there are still not enough trained ophthalmologists or hospitals to fight the problem as the average population age increases and likewise the incidence of age-related cataract disease. An exception to this bad news lies within two countries in South Asia, India and Nepal. India and Nepal are not known for being innovative in health and medicine. Still, in 2004, both countries had high cataract surgical rates, a measurement of surgeries performed per million people with blindness due to cataract (WHO 2004).

Ophthalmology experts from around the world are beginning to look to India and Nepal for models in efficiency and cost cutting in health services delivery. Each country contains many high-volume eye hospitals that are circulating blind patients from rural through urban areas and making them sighted.

In this book, I focus on ophthalmology institutions providing a valuable eye health service to the most disadvantaged in their communities, while utilizing an approach that maximizes their self-sufficiency and self-governance. The four high-volume eye hospitals I describe include: non-profit Aravind Eye Care System in India (est. 1976); non-profit Tilganga Institute of Ophthalmology in Nepal (est. 1992); non-profit Lions SightFirst Eye Hospital, Loresho in Kenya (est. 1998); and for-profit Sala Uno in Mexico (est. 2011). In the back of the book, you will find their organizational charts. Each high-volume eye hospital provides access to primary, secondary, or tertiary levels of eye health care.

The lowest level of eye health care, primary, involves vision screenings and eyeglasses (on par with a US optical shop). Secondary eye care centers involve all the care provided at the primary level as well as outpatient cataract surgery and a few other limited services. This is similar to a private clinical ophthalmologist affiliated with an outpatient surgical center in the USA. Finally, tertiary eye care centers provide a wide range of subspecialties in eye health care including: cataracts, cornea, retina, orbit and oculoplasty, glaucoma, uvea, low vision, pediatric ophthalmology, and neuro-ophthalmology. At this level, the care provided is similar to that of an ophthalmology department in a large US hospital, but several times larger. Through endogenous development (i.e., locally initiated, self-reliant development, see Malunga and Holcombe 2014), they have successfully produced their innovations to meet local needs. Experts in India and Nepal have endogenously developed a socio-technical system of linked innovations in science, management, finance, and technology. They challenged the status quo in ophthalmology to address their mission to provide eye health care to poor rural patients around the world.

The Aravind Eye Care System in southern India and the Tilganga Institute of Ophthalmology in Kathmandu, Nepal, are unique among the many eye hospitals in India and Nepal. These two eye hospitals are well known globally for their high-volume, high-quality cataract surgeries that poor patients receive for free or for a nominal fee. Their work is cutting edge in its focus on increasing surgical infrastructure and decreasing surgical costs for eye diseases. Additionally, around the world, Aravind and Tilganga are known for their novel innovations, which include surgical techniques, surgical theater management practices, and the production of low-cost ophthalmic technologies. Furthermore, they have disseminated their innovations to other eye hospitals in South Asia and around the world. To illustrate this, I will discuss two additional eye hospitals in this book: the Lions SightFirst Eye Hospital, Loresho in Nairobi, Kenya, and Sala Uno in Mexico City, Mexico. Additionally, Aravind and Tilganga disseminate their innovations to industrialized countries such as Australia, Finland, and the USA (see Chapter 5, 8, and 9).

The example of South Asian eye hospitals addressing infrastructure needs for controlling eye disease holds valuable insights for our understanding of social entrepreneurship and science and technology transfer in global public health. The work of these organizations helps illuminate issues of economic justice through systems of appropriate technology in global public health, including (1) funding models; (2) the formal and informal relationships through which flows capital, science, and technology. These southern high-tech experts circulate their novel surgical sciences, management practices, and ophthalmic technologies from below, that is, from a position of low socioeconomic and geo-political status in the global field of science (Hwang 2008; Worthington 1993).

As I designed my research study, I deliberately made the choice to interview those from "below"—persons marginalized in some relationship of power. In this study, focusing on "sciences from below" (Harding 2008) indicates an attention to science and technology produced by people who have, in recent times or in the history of Western imperialism, been marginalized at the periphery of science and technology production. Thus, my study uses empirical content derived predominantly from the ophthalmology units that I studied in countries with less social and economic power than Western nations in transnational arenas.

Therefore, in this book, the users and producers of science and technology from below are primarily from less economically developed countries (LEDCs). Other commonly used terms that refer to a similar set of sovereign states include less developed countries, global south, non-Western countries, developing countries, the third world, and low-income countries. I prefer the term less economically developed countries because it is comparative, relational, and points to a specific power relationship that is based on global domestic product (GDP) per capita Purchasing Power Parity (PPP). The broader term of developing country dismisses the ancient history, education, artisan culture, and religion preserved for many centuries in active, every day, sites in Nepal and India. For example, the ancient art of Nepalese pagoda architecture was transferred to China in the 1270s when the emperor invited Arniko to create the White Stupa Temple (Miaoying Temple) in Beijing (Singh and Bhuju 2001). The narrower term, less economically developed country, keeps the comparative element, but points toward the uneven accumulation of economic privilege in some countries over others that is a direct result of past colonial projects and recent globalization of finance (Escobar 1994; McMichael 2010; Pieterse 1991, 2000; Wallerstein 1974), including poverty capital (Roy 2010). The word economic development invokes capital, jobs, incomes, and taxes. The precision of the term means that it raises fewer inappropriate comparisons about lack of culture and lack of values. By using the term less economically developed country, I am attempting to avoid causally associating economic privilege with epistemic privilege or scientific prestige (although often these forms of privilege go hand-in-hand; see Englander 2014).

Usually, questions about the creation and transfer of innovative science and technology start with research in core countries of the world-system that already have a high degree of economic and epistemic privilege. In contrast, my research started with the assumption that innovative science and technology can and does start from persons (or countries) in marginalized (or peripheral) positions of power. I started this global ethnography (Burawoy 1998, 2000) with two questions:

1. What explains the emergence of alternative high-tech solutions combined with social enterprise to address a set of problems common to the rural poor in less economically developed countries instead of wealthy countries?
2. How are these innovations produced in less economically developed countries being disseminated throughout the region and around the world?

For more details about my methodology, please see Chapter 10, which describes my process of multi-sited, extended case method global ethnography (Burawoy 1998, 2000).

While acknowledging the importance of marginalized standpoints for creating new innovation, this book does not celebrate such knowledge and insight as inherent to resource-constrained individuals, organizations, or states. Essentializing creativity as a characteristic of impoverished people is irresponsible (Birtchnell 2011, 2013). Such celebratory discourse overlooks the asymmetry (between innovators in well-resourced versus poverty-stricken areas of the world) that shapes the necessity for the poor to innovate in spite of the risks to themselves and their livelihoods (Birtchnell 2009).

This book avoids such celebratory discourse; instead, it explores the structural opportunities and constraints for innovation from below. I unpack the historically contingent emergence of innovative, community ophthalmology eye clinics and eye hospitals in the global south. Contrary to the dominant twentieth-century policy narrative among international development professionals, my study of South Asia's development and distribution of self-organized high-tech innovation reveals that subordinate networks of high-tech experts from less economically developed countries have the potential for both innovation and development in global fields of science.

The subordinate experts in this book are community ophthalmology professionals: community eye healthcare workers, ophthalmologists, hospital managers, epidemiologists, optometrists, paramedics, and other allied health professionals. They typically provide eye health services to a large number of poor, blind and low-vision patients, and track population-wide outcomes. Likely as a result, their pattern of spending on technologies, consumables, etc., skews toward high volume and low cost. The eye health services provided by community ophthalmology professionals ranges from simple screening for vision problems to more complex surgical correction for eye diseases. Frequently, but not always, community ophthalmology professionals are embedded in international networks.

US ophthalmologist, Dr. Patricia E. Bath first defined the term community ophthalmology in her 1976 presentation to the American Public Health Association meeting in Miami, Florida, as "the discipline of blindness prevention utilizing the methodologies of public health, community medicine and clinical ophthalmology" (Bath 1978, 1913 citing Bath 1976). She was the first to coin this term in the peer-reviewed scientific literature written in English (Bath 1976, 1978, 1979). In 1970, primary health care was a newly imagined agenda inspired by Chinese barefoot doctors and propagated through the World Health Organization (WHO) 1978 Alma-Ata Declaration (Chorev 2012, 66–79; Xu and Hu 2017, 143; WHO Executive Board, 55 1974). Dr. Bath made integrating eye health care into primary health care the cornerstone of her new program of community ophthalmology (Bath 1976, 1978, 1979). This was a controversial argument for her to make to the US public health community and the US ophthalmology community In the 1970s and 1980s.

1.2 Blindness and Cataract Surgery as a Socio-Technical Regime

Of the many diseases that affect human health around the world, blindness is important to study because it affects such a large number and has such a devastating impact on identities and livelihoods. Blindness in Asia is interesting for a variety of reasons. The first couching surgery to correct blindness due to cataract was first performed in southern India more than two-thousand years ago (Elliot 1917; Wilson 1988, 3). Seventh-century records from China show Indian men with couching needles (Deshpande 2000, 371). Thus, South Asia appears to be an important site over time for investigating and treating eye diseases.

Cataract disease causes most of the avoidable blindness globally and therefore has been the focus of programmatic efforts by multilateral agencies such as the World Health Organization and by international non-governmental organizations such as the International Agency for the Prevention of Blindness and the Lions Clubs International Foundation. After cataract disease, the non-communicable disease of glaucoma causes the second highest number of patients with blindness at 8%. Trachoma is one of several other eye diseases that cause blindness. At present, trachoma and other diseases that damage the cornea of the eye account for only 7% of avoidable blindness (Pascolini and Mariotti 2012). As a communicable disease, trachoma is widely known because of the highly publicized efforts of several civil society organizations (e.g., Sight Savers International and the James E. Carter Center Trachoma Control Program) working over many decades to address this disease in Africa. Eye diseases that damage the cornea can often be corrected through surgery. Eye bank technicians excise intact corneas from the donated eyes of deceased persons, and ophthalmologists then surgically implant the corneas into patients to restore their sight.

Cataract disease likewise requires surgery for restoring sight. Therefore, the efforts of eye hospitals such as Tilganga and Aravind have focused on creating human and physical infrastructures to meet the demand for cataract surgery. As part of their work, they created a new surgical technique for cataract called small incision cataract surgery (see Chapter 6).

I discuss five types of cataract surgery in this book. These include intracapsular cataract extraction (ICCE), extracapsular cataract extraction (ECCE), phacoemulsification (Phaco), mini-nuc, and small incision cataract surgery (SICS). Every surgery performed to remove a cataract is a derivative of either ICCE or ECCE (see the Glossary). Each cataract surgery involves, at minimum, removing the opacified (or clouded) natural lens (typically a diameter of 8–9 mm) from the eye. As time passes, the innovations in surgical technique, and advances in ophthalmic products (called consumables), result in: smaller incisions, fewer costly sutures, shorter recovery periods, and better visual outcomes for the patients who undergo cataract surgery.

My initial example of an incumbent socio-technical regime in the global field of ophthalmology is phacoemulsification. A system builder and the inventor of the phacoemulsification probe, Dr. Charles D. Kelman, found to his chagrin that government policies and regulations are key to the growth of any socio-technical regime. In clinical ophthalmology, one might compare the phacoemulsification probes of ophthalmologists to the drills of dentists—an ubiquitous and taken-for-granted tool for quickly restoring health to their patients. For the field of ophthalmology, the common idea is that Phaco is the gold standard for cataract surgery (Hillman 2017). This, however, was not always true. Before Phaco was the gold standard, ICCE was the gold standard in cataract surgery (see Chapters 2 and 5).

Dr. Kelman had to argue with his peers in the field of ophthalmology in the 1970s in order to convince them of the utility of his new ECCE-derived phacoemulsification technique. In 1973, US federal regulators decided that no Medicare payments should be made to any ophthalmologists who were using phacoemulsification, as it was deemed an experimental procedure (Ocular Surgery News U.S. Edition 2004; Hillman 2017). This was bad news for phaco: medicare payments were a significant source of income for ophthalmologists performing cataract surgery on an aging US population.

Dr. Kelman is an example of a heroic inventor who had to work as an opinion leader (see Rogers 2003); he had to convince his peers that his new surgical technology practice was useful and could provide better outcomes for patients than the conventional procedure of the time. He was successful; by the early 1980s, Phaco went into clinical trials and US medical schools quickly adopted it for training ophthalmologists (Ocular Surgery News U.S. Edition 2004).

A socio-technical regime includes elements such as: governmental regulation; economic capital; technological artifacts; networks of experts; an education pipeline of technicians in training; and other supporting social, economic, and technical infrastructures (Geels 2002; Hughes 1994). A socio-technical regime is large and embedded in a socio-technical landscape (Geels 2002; Hughes 1987, 1994). The socio-technical landscape is the environment external to the socio-technical regime, to include macroscale politics, values, culture, and economics as well as the physical environment (Geels and Schot 2007). This book looks closely at global networks of medical experts, biomedical companies, and users. Therefore, the socio-technical landscape physically stretches worldwide and operates through globalization (Ritzer 1996; Worthington 1993).

The socio-technical regime, over time, wields increasing influence over the development of new technologies. Historian Thomas Hughes (1987, 62) suggests that, "Radical inventions, if successfully developed, culminate in technological systems." A socio-technical system grows through the efforts of system builders who build networks. Additionally, the socio-technical regime grows through economies of scale and scope. Economies of scale decrease the unit cost per product because of the efficient production of a high volume of products. In economies of scope, the same flexible equipment (or people) can make a variety of products efficiently and therefore attracts the design of new products (Hughes 1994). For example, using phacoemulsification involves one-time costs in the form of training and the purchase of the machine. However, it also involves repeated costs in the form of ophthalmic consumables, consistent electricity supply, and maintenance. Within the Phaco-regime, economies of scope arise from training infrastructure that has developed in teaching hospitals around the world to train ophthalmology residents to perform surgery. Economies of scope also involve employing biomedical engineers, instrument technicians, ophthalmologists, and ophthalmic assistants to design, repair, use, and clean expensive phacoemulsification surgical equipment.

The Phaco-regime is dominated by multinational firms and physicians located geo-politically in the global north, to include: Apollo Optical Systems (New York), Bausch & Lomb Surgical (California), Johnson & Johnson Vision (Florida), STAAR Surgical (California), Carl Zeiss Meditech (Germany), Ophtec (Netherlands), and Hoya Vision Care (Japan). One of the market leaders in ophthalmic consumables and equipment is Alcon, Inc. (Data Monitor 2008; Medical Devices and Surgical Technology Week 2006). Alcon is a company that produces ophthalmic consumables as the second largest division of Novartis. It also purchased CooperVision (California) and through that company owned Cavitron Equipment Corp. (New York), which was the original manufacturer of the Kelman-Cavitron phacoemulsification probe (Hillman 2017).

Originally, Alcon was founded in Texas—its name shortens and combines the two founders' family names. Presently, Alcon is headquartered in Switzerland (Novartis 2013). It employs 1550 employees in research and development spread across laboratories in the global north and specifically in Japan, the USA, Spain, and Switzerland (Data Monitor 2008). As is typical of a multinational company, Alcon has manufacturing facilities all over the world, including in Belgium, Ireland, Germany, the USA, and Switzerland (Data Monitor 2008). In these facilities, Alcon produces a variety of ophthalmic consumables, instruments, and equipment. These include pharmaceuticals (e.g., eye drops and glaucoma medication), consumer products (e.g., contact lenses), and surgical products and equipment (e.g., intraocular lenses, glaucoma and retina stents, phacoemulsification machines). Alcon's most popular product is the foldable AcrySoft® intraocular lens (Data Monitor 2008).

Socio-technical regimes have momentum: As time increases, and the socio-technical system grows, the landscape that used to shape it has less influence, while the regime becomes more entrenched, ossified, and stable. With this stability, it is harder for the socio-technical regime to change its technological trajectory (Hughes 1987, 1994; Geels 2002, 2005; Geels and Schot 2007). This momentum is visible by the waning of societal influence on the elements of the system and the waxing of the system's influence in shaping societal problems and outcomes (Hughes 1987, 1994).

The Phaco-regime has momentum in the global field of ophthalmology. Multinational companies such as Alcon demonstrate the momentum of the Phaco-regime. For example, Alcon features largely in philanthropy: it regularly donates equipment to various eye units around the world. Thus, it is likely that Aravind and other eye institutions in less economically developed countries count Alcon among their international partners. Additionally, as a multinational company, Alcon's sales are global, with the larger share, 52.3%, outside of the USA. Indeed, 15.5% of Alcon's sales are from emerging markets, e.g., Brazil, India, China, and so forth (Data Monitor 2008). The global sales of products by multinational companies such as Alcon, Zeiss, and Hoya help to increase accumulation of capital in the global north. Ophthalmologists and wealthy patients in the global south may benefit from these products on an individual basis, but there is no corresponding national economic development in less economically developed countries.

Meanwhile, many international development practitioners are interested in a general model of endogenous technological development that actually works for countries in the global south. Two concerns among postcolonial science and technology studies, especially among subaltern historians of science, are to provincialize Europe (Anderson 2002; Arnold 2005; Chakrabarty 1995; McNeil 2005) while demonstrating the complexity of intercultural exchanges of knowledge and technology (Fan 2012; Raj 2010).

This book addresses these two concerns by offering a general theoretical model and correlating concepts. Firstly, by conceptualizing interlocking innovations, the book describes the production of linked innovations in technique, product, and process. Secondly, by conceptualizing contestation, the book explains how challengers from niches in the global south contest global knowledge hierarchies in a socio-technical regime under the control of incumbents in the global north. Finally, by describing the general theoretical model, the dual regime thesis, the book explains the emergence of a global socio-technical regime from a particular region of the world, South Asia, which has grown in scale and scope to encompass many countries of the global south.

1.3 Scaling Up Development in Appropriate Technology

Several theories account for science, technology, and international development; the majority have technology transfer as a major component. Historian of science, George Basalla's diffusion thesis (1967), states that science and technology transfers from Empire to Colony (the West to the Rest). This diffusion thesis is, unfortunately, implicit to many development experts' work involving science and technology transfer. As a result of their experience rebuilding Europe through the US Marshall Plan, such experts as early as 1948 began to believe that they could extend this plan to successfully transfer technology to the less economically developed countries in the non-West or global south (Seely 2003, 13). The invisibility of Basalla's thesis among development experts means that the directionality of technology transfer from a wealthy industrialized global north to a less economically developed (but historically and culturally developed) global south is rarely questioned (Pollock 2014). As a result, alternative forms of development are underexplored.

After withdrawing their imperial forces from colonies, Western nations emphasized linear and incremental change through progressive stages of technological implementation in economic development projects within their former colonies. This theory of national economic and social change has had a different scientific basis over time, but typically highlights a Western definition of linear progress through diffusion (Pieterse 1991). Like many theories, developmentalism was created from the perspective of those in power, in this case, Western development experts (Pieterse 1991).

Scholars studying international development have critiqued developmentalism (Escobar 1994; Pieterse 1991, 2000). Beginning in the 1970s, dependency theory has long challenged developmentalism, saying that,

> the economic structures of contemporary underdeveloped countries is …. the result of being involved in the world-economy as a peripheral, raw material producing area, or as [Andre Gunder] Frank puts it for Chile, 'underdevelopment … is the necessary product of four centuries of capitalism itself'. (Wallerstein 1974, 392)

The work of Frantz Fanon has been a strong influence on dependency theorists. Fanon was a psychiatrist and African liberation activist who had earlier argued that the "Third World literally created the Modern World" (Ouaissa 2015 citing Fanon 1961, 58). Many of the successes of the First World, or the global north, comes at the rarely discussed cost of extracting resources (mineral, epistemic, agricultural, etc.) from the Third World or the global south (Harding 2008).

Dependency theory points toward why high-technology transfer from the global north to the global south tends to fail. Typically, such high-technology transfer is one way, local capacity is not developed, culture and values are not considered, and, most importantly, the power dynamics between countries that shape directionality of science and technology flow remain unaltered. The types of projects that international development experts typically conduct continue to originate primarily from government agencies or development organizations in the global north and are disseminated, one way, to other institutions or agencies in the global south (Packard 1997; Pollock 2014). Likewise, health technology transfer is typically unidirectional from the global north to the global south or from urban to rural areas (WHO Executive Board, 55 1974). The diffusion thesis remains alive and well because there is a strong-thread of technological determinism in Western development aid (Cherlet 2014; Visvanathan 2015 [2001]).

Despite opposing evidence and theoretical critique, developmentalist ideology persists among international development professionals, nationalists, and wealthy philanthropists (individuals and institutions). The myth of linear modern development permeates all discussions of national economic development. Fanon furthermore suggested that, because they believe this myth, those in authority (elites from both the global north and the global south) are not attentive to the power structures of exploitation, extraction, and racism that have characterized past colonialism and continue to characterize neoliberal globalization (Grosfoguel and Cervantes-Rodríguez 2002, xxv–xxvii; Ouaissa 2015 citing Fanon 1961, 98). Instead, development practitioners point toward the outcomes of these unequal power structures—the various deficits, and lacks—and misidentify them as the problem that a linear international development program can solve (Escobar 1994; Nieusma 2007).