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The Future of Innovation Studies in Less Economically Developed Countries

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Abstract

In this paper, we argue that there are patterns of innovation occurring in less economically developed countries (LEDCs) that have been historically overlooked by the innovation studies literature, including the literature on innovation systems and the triple helix. This paper briefly surveys cases in agriculture, banking, biomedicine and information and communications technologies that demonstrate organizational, scientific and technological innovation in Africa, South Asia, and Brazil. In particular, we track new developments in two distinctive patterns within LEDCs: (1) civil society as a site of innovation and; (2) innovation through appropriation. By systematically uncovering patterns of innovation in LEDCs, science and technology policy scholars may make new theoretical gains in innovation studies that can potentially contribute to innovation policies in the global South.

Keywords

Developing countries; innovation studies; NGOs; civil society; less economically developed countries; appropriation

INTRODUCTION

Science and technology policy studies have been centrally involved with understanding processes of innovation. Here we broadly define innovation as changes in organizational processes (as well as quality, safety and management sciences) that facilitate the production of technology, science and services. While we recognize that innovation is commonly meant to refer to changes in products themselves, collapsing the definition of innovation into that of mere invention conceals much conceptual richness (Mytelka 2000). As the role of innovation in catalyzing economic development has become increasingly appreciated by scholars and policy makers alike, the importance of science and technology policy studies for development has become progressively more obvious (Lorentzen 2010; Metcalfe and Ramlogan 2008; Viotti 2002). However, innovation in developing countries is subject to different challenges of capital and infrastructure than innovation in industrialized nations; therefore it cannot necessarily be explained by the same concepts used to explain innovation in developed countries (Lorentzen 2010; Metcalfe and Ramlogan 2008; Mytelka 2000).

While innovation in less economically developed countries[i] (LEDCs) is a topic that we believe is neglected by science and technology policy scholars, this was not always the case. For example, during *Minerva’s* first decade (1962-1972), 105 out of 400 articles explicitly dealt with LEDCs, while in 2010 and 2011 only one such article has appeared. During that first decade, science and technology policy scholars thought that LEDCs did not have enough resources and expertise to solve their developmental problems; they needed to educate their elite in the West, and technocrats from Europe and America needed to advise them on how to grow the economy. For example, the first editors of *Minerva* stated that in all of Africa and Asia (except for India), there was not sufficient scientific community “capable of sustaining a public opinion appreciative of the accomplishments and value of modern scientific and scholarly research” (The Editors 1962), and they encouraged the top students from LEDCs to study in Europe and America so that they could return to their home countries and train the population (Moravcsik 1966).

Our analysis begins by highlighting three factors that are important to consider in understanding innovation in less economically developed countries. Firstly, the mainstream economic framework imposed on LEDCs by the “Washington Consensus” (i.e. the World Bank, IMF, G8, etc.) focused on neoliberal structural adjustment policies. These policies were imposed based upon the (often incorrect) assumption that they would enhance economic, science and technology development of the LEDCs (Harvey 2005;

Kamat 2002; Metcalfe and Ramlogan 2008; McMichael 2000). Neoliberal structural adjustment policies involved a rolling back of government provided services in LEDCs (Peck and Tickell 2002), in the belief that such services should or would be provided through the private sector. In the absence of a robust private sector, this often meant a proliferation of domestic non-governmental organizations (NGOs) providing services. These NGOS are typically funded by private donations, international NGOs (INGOs), foreign governments, or the United Nations. Secondly, a small number of countries (East Asian “Tigers”) proved adept at linking an emergent innovation capacity to economic growth (Hou and Gee 1993; Kim 1997); subsequently they have earned the misnomer[ii] of newly industrialized nations. Thirdly, new intellectual frameworks for understanding the role of science, technology, and innovation in development were emerging from a number of disciplines to explain such innovation capacity in industrialized and newly-industrialized nations.

Indeed, since the 1980s, scholarship leading to concepts such as “innovation systems” and the “triple helix” has offered a challenge to neoliberal economics by revealing complex institutional dynamics behind economic development that were not acknowledged, let alone addressed, by “structural adjustment.” However, this work was created primarily using comparative case studies of the wealthy countries of the global north. In a literature survey that specifically focused on innovation studies of low-income countries (or the world’s ‘bottom billion’ people) between 1997 and 2008, Lorentzen argues that while innovation is occurring in low-income countries, the analyses of such innovation by scholars are sporadic, country-specific (instead of comparative) and demonstrate idiosyncrasies (instead of elucidating patterns; 2010). Absent from this sparse yet diverse literature has been any systematic theoretical or analytical approach, especially in regard to key questions of: local capabilities, linkages between different sites of innovation, and distinct forms of learning (Lorentzen 2010).

In this paper, we will discuss two patterns of innovation in less economically developed countries that we believe are important in this regard: non-governmental organizations as strong innovators, and governments as innovators through technological appropriation. To illustrate the patterns we have identified four cases of innovation in: agriculture, banking, biomedicine and information and communications technologies (ICTs) in the global south.

Innovation Systems and Triple Helix

Neoclassical economic approaches to studying innovation tend to neglect the importance of institutions (especially those related to scientific and technological capacity) and to treat all innovators as if they were rational agents (Lundvall ed. 2010 [1992]). Innovation systems and triple helix approaches have offered a corrective to these blind spots, but we argue that they should be broadened to include more discussion of the third/ civil society/ voluntary sector as a site of innovation.

Research on innovation systems has focused on multiple actors including governments, universities, industry and capital to explain innovation at the macro level (Dosi et al eds. 1988; Lundvall ed. 2010 [1992]; Nelson ed. 1993). Innovation requires learning formally through research and development and informally through organizational activities and the creation of intraorganizational linkages (Lundvall ed. 2010 [1992]). The innovation systems perspective is valuable because, if deployed correctly, it can go beyond capital and markets to look at the context in which innovation is embedded including universities and government (Lundvall ed. 2010 [1992]).

The triple helix concept posits that the previously siloed institutions of state, university, and industry frequently interact, and that there are important intersections where hybridized forms of organizational work occur (Etzkowitz and Leyesdorff 2000). The triple helix concept suggests that innovation occurs in a nonlinear process through systems that are always in an endless transition (Etzkowitz and Leyesdorff 1998, 2000).

Innovation system analyses include the history of markets and the importance of organizational learning in firms, between firms, etc. for the maintenance and growth of the system (Lundvall ed. 2010 [1992]; Nelson and Winter 1985). For example, with the new knowledge economy the university is more important not because it is a primary site where knowledge is produced, but as Metcalfe (2010) argues, because universities serve as a central space for informal contacts and social networking.

One weakness of the innovation systems concept is that it does not fully address patterns of innovation that are more commonly found in less economically developed countries. Innovation systems literature has little attended to system-building in the global south, the power dynamics of learning, and how innovation can be environmentally sustainable (Lundvall ed. 2010 [1992]). Innovation systems scholarship has also neglected service-providing non-governmental organizations (NGOs), advocacy organizations, member associations, and other civil society organizations in the innovation process (Krishna and Turpin 2007), in favor of a strong focus on firms, universities, and governments. This oversight is particularly acute given the increasing importance of non-governmental organizations in innovation and development in LEDCs.

PATTERNS OF INNOVATION IN LEDCS

In this section, we briefly explore how science and innovation policy studies can be enriched, particularly with respect to LEDCs, through insights from science and technology studies scholarship focusing on domestic NGOs as innovators dependent upon external/foreign funding (Shrum 2000), and on professional users as innovators through technological appropriation in LECs (Odumosu 2009, 2011; Williams 2011). Our four cases in agriculture, biomedicine, banking, and ICTs examine INGOs versus country-based domestic NGOs on regional innovation (pattern 1), and public-private partnerships versus self-funding on country-specific innovation (pattern 2). Recognizing NGOs as strong innovators (pattern 1) and governments as innovators through appropriation (pattern 2) will be important to effectively shape science, technology and innovation policy of the future within LEDCs.

Pattern 1: NGOs as strong innovators in regional areas that are less economically developed

Many innovations occurring in LEDCs stem from the third sector (or civil society sector) in part because nongovernmental organizations operating in LEDCs have capital to invest in science projects, are interested in developing new technologies and have strengths in organizational processes. The following two examples, the Alliance for Green Revolution in Africa and the community ophthalmology NGOs in South Asia, demonstrate how civil society can play a central role in innovation systems of regional areas (that are less economically developed) instead of individual LEDCs.

INGO Implements Market-led Technology as Agricultural Innovation in Africa

The Alliance for Green Revolution in Africa (AGRA) is an INGO that may become a powerful force for agricultural innovation in Africa. AGRA was started in 2006 with initial funding from the Bill and Melinda Gates Foundation and the Rockefeller Foundation (AGRA 2011). The goal of the AGRA is to achieve food security for Africa by helping smallholder farmers become more efficient through better training, seeds, soil, and financing, and giving the farmers access to markets, transportation, and information (AGRA 2011). AGRA hopes that the output of a smallholder farmer can double or quadruple, and that they are able to “reduce food insecurity by 50%, double the income of 20 million smallholder families, and put at least 15 countries on track for attaining and sustain a uniquely African Green Revolution” (AGRA 2011).

Unlike the previous agricultural development strategies in Latin American and Asia that focused on industrial (“green revolution”) agriculture, AGRA focuses on developing the abilities and output of small shareholder farmers in Africa. Many believe that multinational corporations that have been central to advancing green revolution technologies can hurt agriculture development in Africa because they can cause local agriculture knowledge and skills to atrophy and because they distort markets (Holt-Gimenez 2008). AGRA employs a “market-led technology strategy” to encourage a distinctive green revolution in Africa (Toenniessen, Adesina, and DeVries 2008). There

are three components to AGRA's market-led technology strategy: enhance soil productivity, plant more resilient crops of African staple foods, and build better markets to help farmers acquire input goods like seeds and fertilizers and to make it easier for farmer to sell their crops (Toennisessen, Adesina, and DeVries 2008). AGRA's model focuses on small and medium size enterprises, rather than large corporations and farms, because such enterprises account for more than 70% of agriculture output in Africa (AGRA 2011; Toenniesen, Adesina, and DeVries 2008). Proponents believe that if AGRA can change the farming output of small and medium farmers, it will greatly improve the food production of the continent (Toenniesen, Adesina, and DeVries 2008).

Another key aspect of AGRA's model is its role creating linkages among agri-food actors in order to build knowledge and support smallholder farmers. The organization builds links within Africa between, African scientists, African farmers, and African governments studying agriculture problems; it funds seed and farming technique research; and it sponsors students getting advanced degrees in plant breeding (Blaustein 2008; Toenniesen, Adesina, and DeVries 2008) in degree programs such as integrated soil fertility management and applied agricultural economics[iii].

One key scientific effort that AGRA also funds is plant breeding research. Plant breeding is at the core of developing healthy and plentiful crops that have high yields and that are pest and disease resistant. AGRA has funded research on a variety of African staple crops such as maize, rice, sorghum, and cassava (Blaustein 2008) and other crops[iv] including soybeans, cowpeas, banana and teff.

AGRA's combination of international political prestige and robust financial support creates potential to shape African agriculture policy and research and help African farmers be more innovative. As an example of their political prestige, the chairman of AGRA's board is Kofi Annan, the former United Nations Secretary General (AGRA

2011). Annan has traveled around the world explaining the necessity of small farmers and his stature has given him access to a variety of forums and world leaders (AGRA 2011). Similarly the large amount, and long-term consistency, of financial support from the Gates and Rockefeller foundations may help AGRA be successful where past attempts to catalyze a green revolution in Africa have failed (Toenniesen, Adesina, and DeVries 2008).

In summary, AGRA is adopting an integrated approach to becoming a strong regional innovator, instead of focusing on individual developing countries. It develops agri-food markets, supports small farmers, funds scientific research, and gives out education scholarships. Thus it performs many of the functions of the actors in the triple helix, and as such it represents a model for LEDC innovation that deserves further study by innovation scholars seeking to better understand and encourage innovation at the regional scale in the global south.

South Asian Self-Sufficient NGOs Produce Local High-Technology

The Indian NGO, Aravind Eye Care System, and the Nepali NGO, Tilganga Institute of Ophthalmology, have created many innovations to provide the poor with cataract surgery[v]. Aravind was founded in 1976 by Dr. Govindappa Venkataswamy. It grew from eleven beds in his in-law’s house to a six-hospital system in southern India thirty years later. Tilganga was founded in 1994 by Dr. Sanduk Ruit to focus on cataract disease; by 2012 it had grown to a two-building complex with additional ophthalmology subspecialties.

A key innovation for Aravind is their cost recovery model, which makes them self sufficient for operational expenses. The model includes three main sources of revenue: the sliding scale fee payment system; the local production and sales of ophthalmic products; and the training of other public health professionals. The sliding scale fee payment system allows more affluent patients to pay a higher cost and receive more

amenities for their cataract surgery. The fees charged to the wealthy (40% of patients) then provide free (or subsidized) eye care services (including surgery) to the poor (60% of patients). Remarkably, Aravind does not require that patients supply proof of poverty (Rubin 2007). Through their training programs, Aravind has spread this cost recovery model to many other non-profit eye hospitals in the global south including the Tilganga Institute of Ophthalmology in Nepal.

Both Aravind and Tilganga have introduced technical innovations as well. In the late 1990s/early 2000s, surgeons at Aravind and Tilganga reinvented small incision cataract surgery for use in the surgically difficult white cataracts present in many of their rural, poor South Asian patients (Williams 2011). Additionally, both NGOs locally manufacture low cost intraocular lenses (IOLs). In the 1980s, before low cost IOLs were available for developing countries, the very unsuitable “appropriate technology” in LEDCs after cataract surgery was “coke-bottle” glasses. These glasses do not allow for peripheral vision, and are easily misplaced or broken (Mahadevan 2007; Tielsh 1998). However, before either NGO could address this inappropriate technology by developing their IOL manufacturing units, they had to challenge assumptions held by both domestic and international peers about the capability of LEDCs to produce high technology products. Internationally esteemed Western ophthalmologists, the World Health Organization, and the World Bank (a major source of funding for national eye programs in LEDCs) insisted that the domestic production and implantation of lenses in developing countries was not viable because of the high costs of production and the inability to monitor for post-surgical complications (Mehta and Shenoy 2011). The Indian government, in turn, thought that Aravind’s plan would sabotage their national eye program. However, in 1994 India implemented funding for eye hospitals to purchase IOLs that helped drive demand for Aravind’s lenses (Mehta and Shenoy 2011). In Nepal, Ruit and his team, working in a government hospital, faced similar trials. After proposing that the Nepali government create its own intraocular lens manufacturing facility, his

superiors sought to discredit him (Mahadevan 2007). Ruit eventually left the government hospital; with a core team of paramedics and another ophthalmologist he formed Tilganga and through a partnership with Fred Hollows Foundation Australia he created the manufacturing unit.

Since the mid-1990s, both the Tilganga Institute of Ophthalmology Fred Hollows Intraocular Laboratory and the Aravind Eye Care Systems Aurolab have taken advantage of economies of scale and low labor costs to produce inexpensive intraocular lenses for about $11 as compared to $80 or more in rich nations (Mehta and Shenoy 2011). Tilganga is the sole supplier of lenses in Nepal, and additionally sells lenses to other developing countries, as well as Australia and Europe (their lenses are certified with the CE mark, which means they conform to the legal EU requirements for biomedical prosthetics). Aravind’s manufacturing unit claims 10% of intraocular lens sales worldwide (Oregon Public Broadcasting 2005); all revenues are reinvested into the Aravind Eye Care System (Rubin 2007).

In summary, these two South Asian NGOs have created innovative surgical sciences (Williams 2011) and ophthalmic technology to address blindness among the rural poor in less economically developed countries. Additionally they have implemented innovative organizational techniques in the surgical ward and hospital operations so that these patients might receive subsidized or free surgery.

These two South Asian domestic NGOs, having achieved self-sufficiency for operations expenses, now appear well able to establish and maintain the many national and international linkages required to fulfill their missions. In contrast, we see evidence that other domestic NGOs find that linkages to external experts, agencies, and funders can be detrimental to their mission instead of enhancing their opportunities. For example Shamba, a domestic NGO located in Kenya, engaged in participatory agriculture research practices, where smallholder farmers selected topics of scientific inquiry, and together

participated in experimental trials (Shrum 2000). Although this research was successful, Shamba found that too many linkages to other institutions and funders put pressure on their organization; eventually the participatory agricultural research followed the funding to a different split off NGO (Shrum 2000).

The two cases we have described (see Table 1 below for a summary) demonstrate the potentially distinctive role of INGOs and NGOs as sources of ‘high-tech’ organizational, scientific, and technological innovation in regions that are less economically developed. These cases cannot be accommodated or explained by standard innovation system models derived from study of wealthy industrialized nations with access to capital and good (government maintained) infrastructure.

Further exploration of the role of NGOs as strong innovators may also be applicable in wealthy industrialized nations as they increasingly struggle to develop economically and environmentally sustainable innovation in domains such as general medicine and energy production and distribution.

Table 1 NGOs as Strong Innovators of High-technology

	Agricultural innovation	Biomedical innovation
Innovator	The Alliance for Green Revolution in Africa (AGRA); an INGO headquartered in Ghana	Aravind Eye Care System (an Indian NGO) and Tilganga Institute of Ophthalmology (a Nepali NGO)
Innovator funded by	Funded by INGOs	Self-funded from surgeries, training, and selling IOLs; some funding from governments and INGOs
Mission	Double agriculture output of small and medium farmers in Africa	Provide cheap or free eye care to rural and low income Indians
Organizational Innovations:	New models to encourage farmer participation and involvement; building better markets to buy and sell agriculture supplies and crops; funding and supporting research on crop breeding and the education of new scientists	Streamlined surgical ward process and three-part cost recovery
Technological Innovations:	Developing better farming techniques	Developed tools to help with quick surgeries and a low-cost intraocular lens
Scientific Innovations:	Crop breeding	Reinvented cataract surgery techniques

Pattern 2: Governments Reinventing Technology Through Appropriation

Technologies and technological systems are continually co-evolving with new applications to address the requirements of users. While this phenomenon in itself is not novel or surprising, we want to emphasize how the dynamics of LEDC innovation systems cannot be well understood without attending to the process of technological

appropriation[vi]. In science and technology studies, technological appropriation is defined as the process of a user moving from consumer to producer by reinterpreting, adapting or reinventing (Eglash 2004). Science and technology studies, looking primarily at industrialized nations, have conceptualized users as lay people (e.g., Eglash 2004; Kline and Pinch 1996) who become producers in a process of technological appropriation. Other innovation studies have examined the relationship between professional users and the firms who provide them with products and services (e.g., von Hippel, 2004; Lundvall 2009 [1988]). More recent work focused on the global south has conceptualized users as highly educated professionals consuming high-technology and science in LEDCs; these professional users develop the additional expertise to become producers in a process of constitutive appropriation (Odumosu 2009, 2011) and cosmopolitan appropriation (Williams 2011).

Below are two case studies that exemplify technological appropriation by governments. In our first case, a Kenyan telecom company (primarily owned by the Kenyan government) creates a unique mobile banking system targeted for Kenyans who cannot access traditional banking services. The second case briefly examines how the Brazilian government developed open source software that was more cost effective and better matched its needs than proprietary commercial software. In the Brazilian case in particular, the government has to maneuver around the constraints of international commerce and law to protect domestic industry.

Public-Private Partnership Reinvents Mobile Banking for Low-income Kenyans

M-Pesa is a Kenyan mobile banking system that was started in 2007 as a public-private partnership between Safaricom[vii] and Vodafone. M stands for mobile and pesa is a Swahili word for money (Hughes and Lonie 2007).
M-Pesa started as a pilot program at Safaricom; M-Pesa was funded by a £1 million grant from the United Kingdom Department for International Development (DFID) and a matching donation of £1 million from Vodafone (a European multi-national mobile

telecommunications company). The pilot program was a part of a £15 million DFID program to promote public-private partnerships to improve financial service transactions in LEDCs (Hughes and Lonie 2007).

Before M-Pesa, Kenyans did not have a cheap and reliable way to transfer money across the country. Kenyans relied on informal, expensive and unreliable methods of money transfer like giving money to friends traveling to rural areas or using bus companies as money transfer agencies. The Kenyan post office offers a service called PostaPay, but many complained that it was not located in rural areas and that the service often had cash shortages (Mas and Morawczynski 2009). As a result, there was a need for a service like M-Pesa.

M-Pesa allows Kenyans to store money on their cell phone, transfer money to other users and withdraw money from their mobile accounts to receive cash. Two years after its creation M-Pesa had 6 million users and was used by an estimated 65% of Kenyan households (Jack and Suri 2011). About US$ 1.6 billion has been exchanged through the system in the first two years of operation, from 2007 to 2009 (Mas and Morawczynski 2009).

M-Pesa is built upon the preexisting Safaricom mobile network infrastructure. Safaricom is the largest mobile service provided in Kenya; it has more than 75% of the voice telephony market share and strong brand recognition throughout Kenya (Mas and Morawczynski 2009), and its market superiority has helped it roll out M-Pesa across Kenya. Safaricom also had the resources to mass market M-Pesa and provide the financial backing to ensure the system has enough cash on hand to operate. Because Safaricom is a parastatal organization, it could successful navigate banking and communication regulations.

M-Pesa is an example of a technological appropriation that reached the poor. Before M-Pesa, there were other mobile banking systems available for mobile phone users but they

did not fit the Kenyan context. In Western markets the mobile phone banking systems are geared towards high- or middle-income professionals with bank accounts and smart phones. Most Kenyans, on the other hand, have simple phones that only receive text messages, and many Kenyans do not have bank accounts. Instead of adopting previous mobile phone banking software from the west, Vodafone engineers built their own mobile banking system that matched Kenya's market and needs (Hughes and Lonie 2007). Moreover the system had to use current cell towers, bandwidth constraints and retail outlets to provide this service to the community. The developers of M-Pesa could not design a system that required retail stores and customers to buy new hardware systems or special cards (Hughes and Lonie 2007). The result was a mobile banking system that changed how Kenyans conduct business and send money to their families by allowing for cheaper, safer and more efficient money transfer.

In summary, the development of M-Pesa is an example of technological appropriation by a public-private partnership. Kenya (which at the time had a controlling interest in Safaricom) partnered with a European multinational enterprise, Vodafone, in order to create a new mobile banking system that fit the needs of low-income individuals and businesses in the informal sector of the economy. The Kenya case study shows that government can be innovators through technological appropriation.

Brazil Adapts Open Source Software for Government Use

Brazil's adaptation of open source technology provides another successful model of technological appropriation[viii]. Since 2003, the Brazilian government has replaced its software systems with open access programs–software that the users are allowed to edit and distribute without any proprietary restrictions. Many believe that open source software will be beneficial to LEDCs because it allows those countries to develop technology that fits their context; also LEDCs can circulate money domestically by not paying the high user fees to foreign corporations (Camara and Fonseca 2007; Ghosh 2003). Also advocates of open source software in the LEDCs believe that the software can serve as a training tool to help them develop greater capacity in innovation related to

software (International Institute of Infonomics and Berlecon Research GMBH 2002, Camara and Fonseca 2007; Ghosh 2003).

The Free/Libre/Open Source Software (FLOSS) was appropriated in Brazil through implementation by the (at the time incoming) President Luiz Inacio Lula da Silva. The government believed that FLOSS would decrease the expenditures of the government, train and utilize the talents of the population, and strengthen the sovereignty of Brazil (Shaw 2010). It is estimated that between 6% and 10% of Microsoft’s annual revenue is from the Brazilian government (Richter et al. 2009) and that Brazil could save US$120 million by switching to open source software (Kingstone 2005). By switching to open source software, much of this money would be available for productive internal investment, rather than flowing out of Brazil’s economy in the form of the licensing fees paid to companies like Microsoft. As explained by Sergio Amadeu (an official in the Lula administration and one of the leaders of the FLOSS movement), “Brazil has more than the right, it has the need to utilize technologies that enable the growth of its technological autonomy, its participation as a developer of solutions in the information society, the reduction of costs and the expansion of its independence in the face of international monopolies” (Shaw 2010).

The Brazilian government faced challenges from both internal political constituencies and multinational companies who would lose money if Brazil reduced its dependence on external software providers. Multinational companies like Microsoft argued that the new policy would increase the security risks of the Brazilian government’s computer network because the OSS did not include many of the security features of proprietary software. Many politicians, especially those who opposed Lula da Silva and also favored neoliberal approaches to government, argued that the new policy hurt the country’s prospects for developing profitable technology because OSS was free and the government could not profit from the technology that was developed (Richter et al. 2009; Shaw 2010). Amadeu said that Microsoft used drug dealer tactics to hook Brazil on its product, and in

retaliation, Microsoft sued him for slander. The slander case was eventually dropped by the Brazilian courts, but it illustrates the high stakes for software companies and the Brazilian government (Richter et al. 2009; Shaw 2010).

The Brazilian government began its implementation of FLOSS program on national government computers and servers at the social welfare administration and the Ministry of Finance (Shaw 2010). Subsequently, other ministries, including the Ministry of Culture, the armed forces and the Ministry of Science and Technology, followed suit (Shaw 2010). After the program’s first year in 2003, twenty percent of computers in the government used open access software and by 2009 most government computers used Linux or some other open source software (Richter et al. 2009). The transition to FLOSS has been popular throughout Brazil. Twenty-seven Brazilian cities and states have passed laws promoting FLOSS and in general the public supports the transition. The move was also applauded by multinational companies like IBM, CISCO, and Novell (Richter et al. 2009) that have ties to the development of open-source software products and software support services.

The FLOSS movement has strengthened the intellectual capital of the Brazilian IT sector and helped it become a leader in open source in South America. Rather than relying on foreign programmers, through the open source initiative, Brazil developed internal knowledge and capabilities in open source software. Also the initial open source experiment for government computers has carried over to education, and private industry. About 53,000 computer labs for students use open source software and about 73% of companies with over 1000 employees use some type of open source software (Richter et al. 2009).

In summary, the adaptation of open-source by the Brazilian government is an example of technological appropriation. Rather than relying on innovation from wealthy countries in

the global north, Brazil also created its own technology that fit its needs. The Brazilian case study shows that government can be technological appropriators while creating and a domestic software industry. Instead of relying on private industry or academia, the Brazilian government took an established technology, FLOSS, and transformed it to fit Brazil’s context. This case also illustrates Brazil’s growing capacity to navigate complex global innovation landscapes: in the 1990s the nation’s incipient computer manufacturing industry died out when the government, responding to complaints from Apple, shut down a manufacturer that was cloning Macintosh computers (Da Costa Marques 2010).

In the cases that illustrate patter #2 (summarized in Table 2), an old technology is adapted or reinvented to be used in a new context. The key stakeholders in creating these new innovations are governments instead of individual lay users, or professional users. The role of these governments is different from pattern #1 cases, where the African INGO has enough capital and political influence to seek to influence national agricultural policies in the continent, and the South Asian NGOs could challenge international institutions and local governments to perform their mission in the global south. In pattern #2, the Kenyan and Brazilian governments are constrained by international law, and the rules of international commerce. However, within these constraints, they are still able to position themselves as experts about their own country-specific needs. Similar to domestic firms engaging foreign investment, the Kenyan government makes use of external funds and a partnership with a multi-national enterprise to reinvent banking for low-income Kenyans. The Brazilian government makes use of the ‘copyleft’ legal terms from the open-source software and open-access copyright movements. They can make a legal case that they have moved to a low-cost competitor of Microsoft (maintaining the laws of international commerce), while they are simultaneously protecting and developing their own domestic software industry.

Table 2 Governments Reinventing Technology through Appropriation

	Banking innovation	ICT innovation
Innovator	Public-private partnership between Kenyan government and multi-national enterprise Vodafone	Brazilian Government
Innovator Funded by	Initial funding from British government and Vodafone; now self-sustaining	Self-funded
Mission	Provide low-income Kenyans and informal enterprises a new way of managing and transferring money	Provide Brazilian citizens access to low cost government services
Technological Innovations:	A mobile banking system	Developed open source software for government computers

CHALLENGE FOR SCIENCE POLICY SCHOLARS

Above we have described two new patterns of innovation that extend insights described in previous work by innovation studies scholars by looking at new agents and areas: NGOs as strong regional innovators and governments as producers through appropriation. In the first pattern, INGOs and NGOs are strong regional innovators who develop local and regional linkages, and make use of domestic experts and international funding, while creating innovative organizational processes, scientific techniques and technological products. In the second pattern, individual country governments are funded through partnerships with private industry, or self-funded; these governments create context-specific innovations that address a particular national need at low cost. In presenting only four cases, of course, the generality of these patterns remains a challenge for additional research, but our findings complement and add to similarly enlightening cases such as: South African NGOs as innovators in subsistence-agriculture by

developing participatory farming technology (Adey 2007); and high-tech innovation in biotechnology through central planning by governments in communist Cuba (Reid-Henry 2010) and socialist India (Valdiya 2010).

An important topic for future work in the field of science and technology policy studies is to explain the role of NGOs as strong innovators at the regional level, particularly in the global south where there are not necessarily strong government services or planning. NGOs in LEDCs may often engage in a role that is played by firms and universities in standard innovation system models. The NGOs act as firms by providing essential goods and services in LEDCs and may operate as social enterprises with a model somewhere between non-profit advocacy and for profit business (as with the eye hospitals in pattern #1). Moreover NGOs in our cases share characteristics of universities in the triple helix model. The NGOs create linkages between international funders and domestic experts and may produce new knowledge that is used by society (as illustrated by both the agriculture and eye hospital cases in pattern #1). NGOS should be studied more closely to more fully understand their role in controlling capital, creating organizational linkages, establishing value-chains, and encouraging regional economic development through small and medium enterprises in the formal and informal economy. How do these NGOs fit into the innovation system?

Another important topic for future work in the field of science and technology policy studies is to explain the role of governments as technology appropriators, and how this role allows them to navigate some of the neoliberal rules of international law and commerce which often disadvantage LEDCs. The mobile banking system case in pattern #2 encourages us to probe the problems and opportunities in international law and commerce encountered by public-private partnerships (between governments of LEDCs and multi-national enterprises) as they attempt to scale up industrial production of technologies that are appropriate to LEDCs. The open-source software case similarly

challenges science and technology policy scholars to explore how governments in LEDCs can navigate the complexities of international law and commerce while protecting domestic manufacturing or technology production. Insight into such challenges would help governments in LEDCs to understand the feasibility of technology appropriation as a mode of innovation (Jensen et al 2007) in their own contexts.

CONCLUSION

In 2010, Lorentzen advised that new work on low-income countries should be conducted on the connection between external technology transfer and local innovation diffusion, and on community/ participatory/ user-driven innovation. In this paper, we add more focus and direction to this call, and challenge science and technology policy scholars to address distinctive patterns of innovation in LEDCs: the role of NGOs as strong innovators, and of governments as innovators through appropriation. By describing four specific cases in agriculture, biomedicine, banking and ICTs, we have sought to make clear how innovation activities and dynamics in LEDCs may lie outside of the current conceptual mapping and explanatory frameworks of innovation systems and triple helix.

Our view is that that because the intellectual and analytical foundations of innovation systems analysis were largely developed in reference to industrialized and newly industrialized countries, they are inadequate for understanding some of the most interesting aspects of innovation in LEDCs. Such inadequacies may lead to flawed policy prescriptions that dissuade innovators in LEDCs from developing novel and contextually appropriate solutions to their problems (e.g., see Viotti 2002). While we could only offer a few cases, we hope that they are sufficiently rich to stimulate deeper and more creative investigations of innovation in LEDCS. Until more work is developed that systematically determines patterns using individual country and regional comparisons, the role of innovation in the economic development of LEDCs, with their challenges of constrained resources and poor infrastructure, will remain inadequately understood, and the potential

contribution of science and innovation studies to successful policies in low-income countries will remain unmet.

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[i] Less economically developed countries are alternatively referred to in this paper as countries of the global south, low-income countries, or developing countries.

[ii] Japan was already industrialized, but is often included in the list of "Tigers".

[iii] We learned about these two specific degree types from emailing Dr. Rufaro M. Madakadze, a Program Officer in Education and Training for AGRA.

[iv] We learned about these other crops from emailing Dr. Rufaro M. Madakadze, a Program Officer in Education and Training for AGRA.

[v] India is described by some as a newly industrializing country, but it nevertheless has one-third of the world’s poor. Both India and Nepal are finding ways to provide eye health care to rural, low-income blind people through the multi-pronged strategy that we will describe.

[vi] Mytelka (2000) and other science and technology policy scholars might call our cases of technology appropriation ‘imitative innovation’, however this concept does not attend to the power dynamics of a user moving from consumption to production (Eglash 2004)

[vii] In 2007, Safaricom was a parastatal organization because the majority of the company (60%) was owned by the Kenyan government (www.safaricom.co.ke)

[viii] Brazil, like India, is considered a newly industrializing country. This example still may be useful to less economically developed countries trying to navigate international commerce and law.