Research Policy xxx (2013) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

Pursuing endogenous high-tech innovation in developing countries: A look at regenerative medicine innovation in Brazil, China and India

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ARTICLE INFO

Article history:
Received 22 August 2011
Received in revised form 17 June 2012
Accepted 21 December 2012
Available online xxx

Keywords:
Sectoral innovation
Regenerative medicine
Technological development
Developing countries
Emerging economies
Innovation systems

ABSTRACT

Few studies in developing countries have examined innovation in an emerging field such as regenerative medicine (RM). Here, we compare case studies of the RM sectors in Brazil, China and India to help understand RM innovation from a systemic perspective. Innovation in developing countries is usually described as a process of reverse engineering carried out by firms, but we argue that this description is not well suited to innovation in an emerging field such as RM. We show here that innovation in new emerging fields can occur in developing countries by diverse processes not yet discussed in the literature. We introduce the main types of actors in RM innovation, look at the interactions between users and producers, and discuss the advantages and challenges of innovating in RM that are faced by the emerging economies. We find that RM innovation in these countries is demand-driven and occurs under conditions unique to countries with lower-resources. We also find that firms play a smaller role in RM innovation at this stage, showing the importance of considering wider innovation actors in the study of novel innovation dynamics.

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1. Introduction

Most sectoral innovation research has until recently focused on developed countries (Malerba and Mani, 2009b). For several decades there has been, however, the belief that specific technologies may play an important role in the advancement of developing country economies. Pérez and Soete believe that certain technologies – or certain stages of a technology's development toward maturity – present developing countries with "windows of opportunity" to catch up (Pérez, 2001; Pérez and Soete, 1988). These windows of opportunity may be influenced via a number of factors, including through the creation of appropriate institutional frameworks, government policies and skilled human resources (Niosi and Reid, 2007). New wave technologies may differ from more traditional sectors with respect to the capabilities required for innovation – these new technologies may require greater R&D and patent intensity, strengthening of the knowledge base, and greater linkages to users (Mytelka, 2006). Pérez and Soete (1988) believe that the "crucial ingredient" for the advancement of developing countries is to enter early into new technology systems, or they risk remaining stuck in a cycle of investing in mature technologies, steps behind the richer nations.

New emerging technologies have been discussed generally in terms of how they contribute to the national innovation systems of developing countries, and what opportunities and challenges they present for those interested in participating in these waves. There has been little discussion in the literature, however, of what innovation in any of these emerging technologies looks like. This paper will begin to address this gap by discussing the process of innovation in one newly emerging field where some developing countries have been active – regenerative medicine.

Regenerative medicine (RM) is an interdisciplinary field that is still very new worldwide. Although the human body is able to recover from some illnesses and small injuries, it remains unable to heal more extensive damage caused by old age, trauma and disease. Increasingly over the last few decades, researchers believe that the regenerative properties of stem cell, tissue engineering and gene therapy based technologies may eventually be the key to more extensive re-growth of damaged tissues and organs. Regenerative medicine is highly interdisciplinary and lies at the intersection of genetics, cellular biology, biomaterial engineering, computer science, chemistry, and medicine, among many others, and is estimated to have a global market value of over $US 500 billion, according to the United States Department of Health and Human Services report (US Department of Health and Human Services, 2005).

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http://dx.doi.org/10.1016/j.respol.2012.12.003

Please cite this article in press as: McMahon, D., Thorsteinsdóttir, H., Pursuing endogenous high-tech innovation in developing countries: A look at regenerative medicine innovation in Brazil, China and India. Res. Policy (2013), http://dx.doi.org/10.1016/j.respol.2012.12.003

Most RM applications are targeted to treat chronic illness, and over 80% of chronic disease deaths occur in low and middle income countries, severely impairing the capacity of low GDP countries to address primary healthcare concerns (WHO, 2005). Capacity in regenerative medicine (RM) is limited in most developing and emerging economies, and there is concern that without their involvement in RM, the resulting products will not be affordable to developing countries and will not reflect their health needs (Greenwood et al., 2006a). Our studies of RM in China, India and Brazil have showed that these developing countries have already developed significant capacity in this field, from basic research to clinical trials (Lander et al., 2008; McMahon et al., 2010a,b).

This paper examines innovation in the emerging technology field of RM across China, India and Brazil. This is one of the first discussions of the process of endogenous science-based innovation occurring in developing countries, and has implications for how innovation in the emerging economies is perceived. We argue that innovation in emerging fields is possible in developing countries, and occurs through processes other than "reverse engineering" not yet captured by the literature. We describe the innovation processes that are occurring and the components of the RM innovation system. We then discuss the implications of our findings for how innovation in developing countries is conceived, including on the role of demand in shaping innovation, and on the unique aspects of RM innovation in those countries.

This paper is structured as follows. We begin in Section 2 with a brief introduction to the literature on models of innovation in developing countries, and describe our methodology for this study in Section 3. We introduce the reader to the process of RM innovation in our countries of interest in Section 4.1 and the key components of the RM innovation systems in Section 4.2, showing that the model of firm-centric reverse engineering is insufficient to capture RM innovation in the emerging economies. We then discuss RM innovation on a more systemic level by showing the user–producer relationships that shape demand for RM innovation, as well as the challenges and advantages to pursuing endogenous high-tech innovations in emerging economies (Sections 4.3 and 4.4 respectively). We end the paper in Section 5 with our main findings.

2. Background

Sectoral systems of innovation (SSI) can be defined as a network of actors and linkages between organizations and institutions involved in the creation, diffusion and use of knowledge within a particular technology or sector. The sectoral system based approach to studying innovation is intended to be a broad, flexible, and adaptable tool that allows qualitative and quantitative comparative analysis across countries and regions (Malerba and Mani, 2009b). Most sectoral innovation studies have been conducted in developed countries, but sectoral innovation focused on developing countries is now on the rise, as indicated by the number of papers presented on sectoral innovation in annual Globelics conferences, and as seen by the publication in 2009 of the first book on sectoral innovation in developing countries (Malerba and Mani, 2009a). Very few studies using sectoral innovation frameworks have examined new biomedical fields in developing countries. While there are no studies of RM innovation in developing countries other than our published case studies, biotechnology has been identified as sector of innovative opportunity by authors using innovation system frameworks (Niosi and Reid, 2007; Thorsteinsdóttir et al., 2004). These papers further point to Brazil, India and China as being among the leaders of biotechnology in the developing world.

The broader innovation systems literature on catch-up of latecomer countries has focused on transitional economies that have succeed in developing rapid economic growth and technological "catch-up", particularly those known as the Asian Tigers: Taiwan, South Korea and Singapore. The literature on technological change in developing countries seems to suggest that their technological trajectory is fundamentally different from that of developed countries. Several models indicate that technologies are acquired from developed countries and then assimilated and adapted by developing countries (see for example Hobday et al., 2004; Kim, 1998; Utterback and Abernathy, 1975; Wong, 1999).

One such model of technological change is Kim's model of technological development (Kim, 1998, 1999). Kim adapts the Utterback model to better reflect developing country advancements, and describes developing country innovation as a process of acquisition, assimilation and improvement. By acquiring mature "packaged" technologies including all manufacturing know-how, latecomer countries can "acquire" technology. Then follows a period of process innovation, in which competition between new entrants encourages improvements in the manufacturing process to improve and differentiate products. Some firms may acquire enough endogenous capacity through this process to make innovative improvements to the originally imported mature technologies and become internationally competitive. This process is opposite in many respects to the development process of affluent countries, and is sometimes referred to as reverse engineering.

Lee and Lim describe different models of catching up based on selected South Korean industries (Lee and Lim, 2001). The models they describe include: (1) path-creating catching up, (2) path-skipping catching-up and (3) path-following catching up. In the first two models, the industry is able to "leap-frog" ahead by skipping steps that previous entrants went through, whereas the third is more similar to the Utterback model, depending on "duplicative imitation" followed by "creative imitation".

Wong similarly describes the innovative process of emerging economies from the perspective of the late-comer, but highlights potential differences in the way these late-comer firms react and develop (Wong, 1999). Wong describes the rapid industrial and technological catch-up of South Korea, Taiwan and Singapore and introduces five models of development that differ in the extent and speed of innovation in the manufacturing process and final product. Wong includes models similar to Kim's, but also describes models in which process innovation is the key goal, or where product innovation occurs in tandem to process innovation. Wong stresses that firms in these emerging countries will evolve different strategies that play to their unique strengths and resources than would be developed by latecomer firms in advanced countries. He first describes several general first mover advantages: early capture of consumers, capture of key resources, and learning curve effect. In addition to the absence of these advantages, latecomer firms in emerging economies suffer from distance from users, distance from leading sources of technology, and shortage of specialized input resources/infrastructure. Latecomer advantages for late industrializing countries include lower resource costs, sheltered markets, and information asymmetry. Knowledge flows from developed to developing countries are larger than knowledge vice versa, owing to the knowledge on developing country firms being less accessible or locked in local languages (Wong, 1999).

Many others have also explored the difficulty of developing technological capacity in emerging economies. For example, the transition dilemma between the 'catch-up' phase and true leadership is explored by Hobday et al. (2004), who describes how firms and sectors move between these stages. Ernst (2002) has explored the innovation systems of developing countries by studying the international networks that allow the import of mature technologies for reverse engineering.

The key similarity between all of the frameworks described above is that the focus is on how *latecomer firms* to a field become involved in the eventual creation of new knowledge. This is the

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