Technological Forecasting & Social Change 104 (2016) 38–56

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

Architecting complex international science, technology and innovation partnerships (CISTIPs): A study of four global MIT collaborations

Sebastian M. Pfotenhauer [a,b,*], Danielle Wood [c], Dan Roos [a,d], Dava Newman [a,e]

[a] MIT Technology & Policy Program, Institute for Data, Systems, and Society, Massachusetts Institute of Technology, 77 Massachusetts Avenue, E40-369, Cambridge, MA 02139, United States
[b] Munich Center for Technology in Society (MCTS) and TUM School of Management, Technische Universität München, Arcisstr. 21, 80333 München, Germany
[c] JHU Systems Institute, Johns Hopkins University, 3400 N. Charles St, Baltimore, MD 21218, United States
[d] Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, 77 Massachusetts Avenue, 1-290, Cambridge, MA 02139, United States
[e] Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, 77 Massachusetts Avenue, 33-207, Cambridge, MA 02139, United States

ARTICLE INFO

Article history:
Received 26 February 2015
Received in revised form 11 December 2015
Accepted 12 December 2015
Available online 30 December 2015

Keywords:
Innovation policy
Research collaboration
Regional development
University partnerships
System architecture
Policy design
MIT
International partnerships

ABSTRACT

Complex international partnerships have emerged as a policy instrument of choice for many governments to build domestic capacity in science, technology and innovation with the help of foreign partners. At present, these flagship initiatives tend to be primarily practitioner-driven with limited systematic understanding of available design options and trade-offs. Here, we present an analysis of four such partnerships from the university sector between the Massachusetts Institute of Technology (MIT) and governments in the UK, Portugal, Abu Dhabi, and Singapore. Using a system architecture approach in conjunctions with in-depth case studies and elements of interpretive policy analysis, we map how in each country distinct capacity-building goals, activities, and political and institutional contexts translate into different partnership architectures: a bilateral hub-&-spokes architecture (UK), a consortium architecture (Portugal), an institution-building architecture (Abu Dhabi), and a functional expansion architecture (Singapore). Despite these differences in emergent macro-architectures, we show that each partnership draws on an identical, limited set of 'forms' that can by organized around four architectural views (education, research, innovation & entrepreneurship, institution-building) and four levels of interaction between partners (people, programs/projects, objects, organization/process). Based on our analysis, we derive a design matrix that can help guide the development future partnerships through a systematic understanding of available design choices. Our research underscores the utility and flexibility of complex international partnerships as systemic policy instruments. It suggests a greater role for global research universities in capacity-building and international development, and emphasizes the potential of targeted cross-border funding. Our research also demonstrates the analytic power of system architecture for policy analysis and design. We argue that architectural thinking provides a useful stepping stone for STS-type interpretive policy analysis into national innovation initiatives in different political cultures, as well as more custom-tailored approaches to program evaluation.

1. Introduction: Complex International Science, Technology, and Innovation Partnerships

Over the past two decades, a growing number of countries have launched large-scale international partnerships between domestic universities and prominent international partner institutions. For example, since 2006, the country of Portugal has launched five major collaborative initiatives with the Massachusetts Institute of Technology (MIT), Carnegie Mellon University, University of Texas at Austin, Harvard Medical School, and the German Fraunhofer Society to "strengthen the country's knowledge base and international competitiveness through a strategic investment in people, knowledge and ideas" (MIT, 2005; Pfotenhauer et al., 2013). Likewise, in 2006, the government of Singapore inaugurated its Campus for Research Excellence and Technological Enterprise (CREATE) as an "international collaboratory of research centers set up by top global universities and research institutes in Singapore [.] that fosters deep collaborations with each other and with Singapore universities [and] establish[es] a reputation as a leading research hub" (NRF, 2006), inviting as many as 10 international partners to CREATE, including University of California Berkeley, University of Cambridge, ETH Zurich, MIT, Technion, and TU Munich. Another example, the new Skolkovo Institute of Technology (SkolTech) – an innovation-geared research university established just outside Moscow – is being built

* Corresponding author at: Munich Center for Technology in Society (MCTS) and TUM School of Management, Technische Universität München, Arcisstr. 21, 80333 München, Germany.
E-mail address: sebastian.pfotenhauer@tum.de (S.M. Pfotenhauer).

http://dx.doi.org/10.1016/j.techfore.2015.12.006

around a suite of collaborative Centers for Research, Education, and Innovation, where local, national, and international partners (including MIT and the universities of Groningen and Delft) come together to jointly work on research projects.

Cross-border activities among universities are not new. However, this new generation of partnerships differs from traditional forms of engagement in several important ways. First, they typically represent *capacity-building agreements*; that is, they are limited-time contractual engagements to build domestic capacity in a specific scientific or technological domain *with the help of an international partner*, after which the partnership may be terminated. Unlike branch campuses or twinning programs, they are not seen as permanent offshore presences, and tend to be driven primarily by the government of hosting country — not by an expanding university per se. Second, they typically *combine explicitly collaborative activities with a set of* (*paid*) *services* provided by one partner to the other. Third, they allocate local taxpayer money to fund research (and a host of other activities) *with and at a foreign partner* university, which stands in sharp contrast to the still mostly national patterns in research funding and institution-building. Fourth, the partnerships are typically *complex*, meaning that they simultaneously address goals in education, research, innovation, institution-building, and policy reform, among others. This differs from more traditional forms of cross-border university engagement, which usually only focus on one of these aspects, e.g. in the form of student exchanges, dual degree programs, or individual researcher collaboration. Fifth, they tend to be *large-scale* initiatives that may last up to 20 years, involve hundreds of people, cost tens to hundreds of millions of dollars (not including potential infrastructure development), and often tie in a plethora of institutions in a consortium-like structure.

These large-scale university partnerships are part of an emergent policy instrument for national capacity-building that we call "Complex International Science, Technology, and Innovation Partnerships" – CISTIPs for short – and that share the above properties of (1) limited-term capacity-build arrangement, (2) hybrid collaborative-consultative efforts, (3) funding foreign institutions, (4) complexity, and (5) scale. In general, CISTIPs are not limited to partnerships between universities, but exist across an increasing range of other institutional and sectoral settings. For example emerging space nations today typically build their first satellite with the help of foreign partners (e.g. companies, government agencies, universities), which equally involves the build-up of research, education, and institutional capacity. Likewise, emerging nuclear nations typically build their first nuclear power plant with the partners in established nuclear powers. The present paper is part of a larger effort to study CISTIPs across sectors and institutional configurations.

Here, we focus on CISTIPs for the case of universities, using four partnerships between the Massachusetts Institute of Technology (MIT) and the governments of the UK, Portugal, Abu Dhabi, and Singapore as case studies. We explore how these partnerships have been constructed to address very different capacity-building goals while relying on similar basic building blocks, and provide a conceptual framework as well as a design toolkit to guide the development of such partnerships in the future.

Note that our goal here is not to assess the success or efficiency of these collaborations from a program evaluation perspective. Rather, it is to understand and systematize the design choices made in existing collaborations and to develop tools for managing their complexity, thus focusing primarily on *structural* aspects. We believe that our insights provide a crucial step for a more adequate evaluation agenda, rooted in a prior understanding of complex goals and unique architectures that evade one-size-fits-all approaches. We further see our work as highly compatible with interpretive approaches to policy analysis as found, for example, in Science and Technology Studies: An in-depth mapping of the policy choices embodied by complex S&T initiatives such as CISTIPs gives us a robust empirical footing for interpreting these policy choices vis-à-vis persistent sociotechnical imaginaries (Jasanoff and Kim, 2009), social expectations surrounding S&T (Borup et al., 2006), and the co-production of technoscientific and social orders (Jasanoff, 2004).

2. Three trends in innovation policy: university-centrism, international linkages, and complexity

This section aims to locate the emergence of complex international university partnership within the current landscape of science, technology, and innovation policy. Over the past decade, innovation policy has been shaped by three major trends: an increasingly central role of universities, a surge in internationalization and research collaboration, and growing complexity of policy instruments. Universities, first, have moved boldly to the heart of national and regional innovation strategies across the globe (Mansfield, 1991; Mansfield and Lee, 1996; Salter and Martin, 2001; Mowery, 2004; Etzkowitz, 2008; Youtie and Shapira, 2008; Cowan and Zinovyeva, 2013; Thorp and Goldstein, 2010). The role of universities for innovation – and particularly their often-cited ability to simultaneously address human capital formation, the creation of new knowledge, and the translation of this knowledge into technological and economic advancement – has been explored by decades' worth of theory development on endogenous growth (Lucas, 1988; Romer, 1990; Aghion and Howitt, 1998; Scherer, 1999) and a flourishing, multidisciplinary literature on innovation theory and practice (see Fagerberg, 2006; Smits et al., 2012 for an overview). Universities are considered cornerstones of national, regional, or sectoral innovation systems (Lundvall, 1992; Nelson, 1993; Edquist, 2005; Braczyk et al., 2004; Malerba, 2005) and seen as key nodes in the globalizing learning economy, in which rapid knowledge diffusion and updating, access to knowledge networks, institutional diversity, and global interconnectedness are increasingly replacing classical growth factors such as the accumulation of capital and labor (Archibugi and Lundvall, 2001; Conceição and Heitor, 2001; Llerena and Matt, 2005). Meanwhile, universities have also become major economic actors themselves: With the rise of "entrepreneurial university" models, universities are increasingly engaged in creating proprietary knowledge and commercializing research through spin-offs or licensing, and are assessed not only by their intellectual but also their economic impact (Clark, 1998; Etzkowitz, 2003; Shane, 2004; Thorp and Goldstein, 2010; Slaughter and Leslie, 1997). As a result, many (if not most) national and regional "innovation strategies" of the last couple of decades have revolved around universities in one way or another.

Second, innovation policy has been increasingly concerned with international linkages. Drawing upon partial roots in international development, the current discourse of innovation policy has closely linked to questions of international knowledge circulation, technology transfer, and gradual convergence to the innovation frontier (Bozeman, 2000; Lee and Lim, 2001; Wei, 1995; Reddy and Zhao, 1990; Amsden, 2001), whereby less-developed nations are imagined to start as adopters and recipients of foreign direct investments, gain expertise through imitation and import substitution, and eventually begin to innovate themselves (Kim, 1997; Lall, 1992; Grieve, 2004). Recent literature has tended to emphasize technological *learning* over transfer, in which opportunities to benefit from technology acquisition in the long run depend on local skills and absorptive capacity, as well as the ability to adapt technologies in a local context (Fransman et al., 1984; Cohen and Levinthal, 1990; Keller, 1996; Lall, 1992; Kim, 1997; Amsden, 2001; Cusumano and Elenkov, 1994).

Another way in which research and innovation policy has gravitated towards internationalization is the surge in research collaborations across fields and institutions, as evidenced by a growing number of scientometric studies (Bozeman et al., 2013; Wuchty et al., 2007; Wagner, 2005; Melin, 2000; Georghiou, 1998; Katz and Martin, 1997; Vinkler, 1993; Luukkonen et al., 1992). Research collaboration has been shown to have positive effects on scientific as well as broader economic productivity (Subramanyam, 1983; Wuchty et al., 2007; Lee and Bozeman, 2005; Dietz and Bozeman, 2005). While collaboration may take many forms, most studies have focused on individual-level research collaborations such as co-authorship or citation networks due to the ready availability of such data, even though their limitations