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Institutionalization of international university research ventures

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ABSTRACT

International research collaborations are widespread, but few have studied those that reach the scale and scope of what we call international university research ventures (IURVs). In an IURV, a university sets up a formal and organizationally consolidated research relationship in a foreign country. This paper puts forward an institutionalization framework to explain the development of IURVs with different forms. Five case studies are presented of IURVs in the countries with the largest number of IURVs involving US universities: China and Singapore. The five cases are examined relative to the elements of the institutionalization framework: nominal, leadership, administrative support, multi-year funding, research targets, formal researcher-to-researcher exchange, visibility, evaluation, and supporting characteristics. The results show that the emergence of IURVs depends on the specific connections between the role of government and the availability of resources with the realization of mutual benefits, leading to different patterns of institutionalization. This variation is in part a function of the degree of involvement of the government agency or department providing the funding for the IURV, which influences retention of the knowledge produced by the IURV in the region through institutionalized mechanisms as well as the development of scientific and technical human capital in the host country. Institutionalization is not a benefit without limits; nevertheless, an institutionalized structure may be necessary if ambitious research-driven goals are to be achieved.

1. Introduction

The involvement of universities in countries other than their home location is a growing trend (Wildavsky, 2010; Lane, 2011; Kosmützky and Krücken, 2014; University of Oxford, 2015). Such international university initiatives are diverse, ranging from offices abroad to coordinate outreach with alumni to fully-fledged overseas branch campuses with degree programs. Among efforts to classify the international activities of universities, Kinser and Lane (2015) identify 12 different types of foreign higher education bases, based on the functions performed by these campuses, from their database of more than 230 branch campuses (globalhighered.org), one of which is the research/campus or site. Studies have also been undertaken of particular cases. For example, the global partnerships of the Massachusetts Institute of Technology (MIT) have been examined using a typology based on a systems architecture and life cycle framework that presents four architectures: bilateral, networked, institution building, and functional expansion (Pfotenhauer et al., 2016). Each model represents one of the international partnerships negotiated between a foreign government and MIT: the bilateral relationship involved the United Kingdom with the University of Cambridge and MIT; the networked model is with seven universities and other research institutes in Portugal; institution-building is with Abu Dhabi; and functional expansion is with Singapore.

Within this diversity of internationalized university arrangements, we focus on one type of initiative: the international university research venture (IURV) in which universities formally set up a research relationship in a foreign country (see also Li et al., 2016; Shapira et al., 2016). Even within this category, we will show that there are variations by location, longevity, and research theme, reflecting differences in goals, management and operations. Yet, these variants notwithstanding, IURVs have one feature in common. They involve a university systematically engaged in research in a host nation other than that of the university's home country. The drivers of such relationships include host country desires for scientific, technological, or reputational benefits as host institutions engage with capable and recognized international universities. Typically, the host country or host institution has something to offer the home institution, be it financial resources to pursue high quality research, access to special research opportunities or raw talent, among other possibilities (Guimon, 2016). The realization of these mutual benefits suggests the need for a mechanism that goes

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beyond co-authorships or research projects between individual scientists in different countries. International university ventures that intend to transcend such informal or smaller-scale collaborations require managerial and administrative support of a certain magnitude and longevity. We denote as "institutionalization" the establishment of formal organizational features and support with a level of permanence that extends further than the usual publishing or project cycles.

The choice of the notion of institutionalization for this study requires clarification. The key point is to distinguish "institutions" from "organizations," as discussed in an extensive body of literature that spans decades (see, for example, Khalil, 1995; Scott, 2013). The broader social and cultural norms that influence organizational patterns and persist in time belong in the institutional order. This study does not focus exclusively on organizational features in a snapshot of time. Rather, it attempts to explain the outcome of a process that takes a significant amount of time and is subject to such broader conditions of the context. For this reason, it is justified to embed our study in an institutional perspective.

In this paper, we seek to probe what specific features of institutionalization raise a collaboration from an informal international research relationship to an IURV, and what kinds of supportive environments lead to their development. A comparison of US IURVs in Singapore and China highlights the variety of institutionalization paths and outcomes. An institutionalization framework is the mechanism we adopt to explain the emergence of IURVs and the differences in their forms. The framework compares and explains these ventures along three dimensions to gauge how they might realize the desired mutual benefits based on the extent to which they acquire certain characteristics in these dimensions. The three dimensions are, first, the extent to which they meet nominal institutional characteristics such as having a formal name and agreement; second the requirements of a fully institutionalized research venture based on characteristics such as formally designated directors and administrative support; and, third, the role of supporting characteristics such as government funding or intellectual property arrangements. The paper demonstrates various degrees and modalities of institutionalization in four archetypes resulting from whether government is (or is not) involved and the degree of structuring in its governance pattern. As detailed in the paper, the four archetypes are government-directed, government-facilitated, non-government-collegial, and non-government-contingent. Although life cycle concepts might suggest the home country would be in a superordinate position relative to the IURV partners in the host country, our case studies suggest that the relationships are more ones of mutual benefit, with a division of labor and distribution of advantages that also address host country societal challenges.

The next part of the paper considers, in the context of extant literature and international research trends, the background for understanding the development of IURVs. We then put forward our theoretical frame and research design, including justifying the selection of five cases of US IURVs in China and Singapore. After presenting each of the IURV cases, we undertake a cross-case analysis to distill and compare key features. The concluding section discusses our findings on the characteristics and trajectories of IURV institutionalization, and reflects on the implications for research management, university internationalization, and policy.

2. Background

Research has become more internationally collaborative as the exponential growth of science alongside constraints on national resources for research make it impossible for any country to be prominent in any field entirely by itself (Katz, 1994; Zinman, 1994). The phenomenon, if not the motive itself, can be identified by observing publication trends. The percentage of scholarly publications indexed in Scopus with authors from two or more different countries rose to 19% in 2013 from 13% in 2000 (National Science Board, 2016). Using another database, the Science Citation Index, Wagner et al. (2015) demonstrate that the percentage of publications in this index with co-authors from different countries more than doubled from 1990 to 2011. Van Raan (1998) shows that internationally co-authored publications involving Dutch astronomers attract more citations, even after controlling for self-citations. Georghiou (1998) links the growth of international research collaboration to mechanisms such as research exchange, workshops, cooperative networks, and large scale scientific equipment and instruments, and national-level initiatives. The author also notes the importance of indirect drivers of international collaboration such as national economic development considerations. Shapira and Wang (2010) confirm that even when countries have national technology strategies (as in the case of nanotechnology), individual researchers and groups extensively collaborate internationally in co-authoring research papers.

While the rise of informal and project-based international scientific collaboration provides a backdrop for the growth of IURVs, other motivations and factors also come into play. Stimuli for the growth of IURVs include the search for effective mechanisms for international scientific collaboration, as well as national, regional, and institutional motivations. We define an IURV as a research arrangement established by a university in one country to partner with a university or other research organization in another country and which involves research facilities or specialized research offices outside of the home country (Li et al., 2016). This definition distinguishes IURVs from "brick and mortar" educational campuses in foreign host countries and spotlights IURVs as a focus of study. Although some IURVs are associated with an educational function at an international campus, we also observe a number of IURVs deriving from researcher-to-researcher collaborations or national and regional efforts to advance research capability. IURVs do not carry the financial and educational quality risks associated with transnational educational campuses (McBurnie and Pollock, 2000; Altbach and Knight, 2007; Olson, 2011; Healey, 2015). Yet tensions can still exist between the IURV host institution and the home university, for instance over intellectual property ownership, research conduct norms, staffing, and health and safety (Borenstein and Shamoo, 2015; Shams and Huisman, 2012; Feast and Bretag, 2005). Shams and Huisman (2016) and Klerkx and Guimon (2017) use the term "dual embeddedness" to describe these tensions in navigating administrative, educational, and research relationships within and between the requirements of host and home institutions.

IURVs represent an institutionalization of cross-national research collaborations. This aspect of the institutionalization of university research is an important topic because, as Herbst (2014, p. 3) notes, research depends "on the institutional or cultural setup in place to foster science." The institutionalization of university research can present as an evolutionary, life cycle process. One might conceive of IURVs as being born of individual researcher collaborations in different countries that progressively move toward greater institutionalization over time. Yet other mechanisms are also at work. Chompalov et al. (2002) and Genuth et al. (2007) chart the rise of administrative mechanisms in research collaboration, suggesting that there are more institutional models than the inter-laboratory cooperation or the large-scale particle physics network. Based on interviews of researchers in 53 multi-institutional research organizations, it is argued that multi-organizational research collaborations are born of funding opportunities, emerging research problems, new methods and instruments, and interactions between scholars. Drawing on this interview dataset, Chompalov (2014) found varying degrees of institutionalization in these multi-institutional research cooperatives in physics and allied sciences based on governance modes. Their finding suggests that although some research collaborations are modest in size and informal, others are of the scale and complexity to require institutional mechanisms to support the research.

Studies of institutionalization of university research have further highlighted the role of broader systemic factors. Bozeman and Rogers highlight the "knowledge value collective" in which researchers

working on the same topic without knowing one another transition into a research collaboration network with explicit agreements (Bozeman and Rogers, 2002; Rogers and Bozeman, 2001). Building on this work, Youtie et al. (2006) examine how multidisciplinary research centers represent an institutional link in the epistemic evolutionary chain from informal nascent networks and knowledge value collectives into new scientific fields and disciplines. Some transnational university relationships have tighter control by the home university, while others allow for more responsiveness to the needs and interests of the host country (Shams and Huisman, 2012). Institutionalization has the potential to traverse these tensions by anticipating issues in advance and providing mechanisms for addressing them; these types of explicit, advance mechanisms have been found to reduce research tensions (Youtie and Bozeman, 2014, 2016).

Yet, multiple questions arise about how this institutional development occurs, and what tensions cause it to persist or stall, especially in the case of IURVs. In this paper, we probe four research questions. First, how do IURVs develop into established institutions to conduct scientific and technological research? Second, what differences in the mechanisms of development lead to differences in the institutional form of these initiatives? Third, what consequences follow from the realization of mutual benefits from the various institutionalization conditions? Finally, what are the policy implications for future international university research ventures?

In addressing these questions, the distinctive contribution of this study is to examine the institutionalization mechanism leading to varied IURV forms in different national contexts and organizational settings. We seek to understand how these ventures grow out of either researcher-to-researcher collaborations or government policies into fully established IURVs with certain features. This differentiates the study from other work on learning and education in host countries, international higher education and research, or collaborations with a specific university (Knight, 2004, 2006, 2007; Cusumano and Elenkov, 1994; Verbik and Merkley, 2006; Bammer, 2008; Corley et al., 2006; Hird and Pfotenhauer, 2016; Pfotenhauer et al., 2016). We anticipate that the institutionalization of IURVs is a key process that highlights the effects of the driving forces of university research internationalization. In particular, the incorporation of various goals, needs, capabilities, and resources into the institutionalization process will shape specific IURVs and these arrangements might include or result in different patterns of allocation of funds, reputational effects, research outputs, balance of power, rules of operation, and the like. The next section discusses the frame through which we probe IURV institutionalization and the factors that lead to varying outcomes and differential allocations of benefits.

3. Theoretical framework and case study research design

The theoretical frame for our analysis draws on institutionalization notions and features adapted from Youtie et al. (2006) (Table 1). This framework contains three basic dimensions with specific attributes along each dimension. The first dimension contains a set of nominal characteristics that an international research collaboration needs to have to meet the basic requirements for our definition of an IURV. Some of these basic nominal characteristics include the involvement of senior researchers from both home and host institutions, joint research projects, a formal agreement such as a memorandum of understanding, and a public name for the venture. The actual manifestation of these characteristics in each case may vary significantly. However, they are suggestive of efforts to move beyond an informal researcher-to-researcher cross-national research collaboration mode. In another word, these characteristics essentially represent the threshold to qualify as an IURV. The second dimension has to do with how an IURV may evolve more institutional mechanisms and thus become a fully-fledged IURV. Characteristics along this dimension include designating an appointed director of the IURV, administrative support, multi-year research commitments, agreed targets for IURV participant research projects, mechanisms for convening or exchanging research personnel, visibility of, and at, the host and home institutions, and performance review. The third dimension of the institutionalization framework addresses the importance of supporting characteristics, which includes features such as whether or not the IURV also fulfills an educational (including degree-awarding) function, access to research granting systems, has a policy rationale, and specific intellectual property mechanisms.

This framework suggests a hypothetical explanation for observed patterns of IURV institutionalization and their variations, namely that these are the result of particular combinations of governance arrangements, rules for participation by local and foreign researchers, access to resources (human, financial and real estate), and arrangements for the distribution of benefits. In other words, observed variations in IURVs in the form of differential institutionalization outcomes are explained by specific differences in the combinations of these factors.

The study is carried out through the application of a multiple comparative case study design. This design examines multiple participant actions in support of generalization to theory based on a broader perspective across different institutionalization and policy settings (Stake, 1995; Yin, 2013). We emphasize that the mode of inference is the one typical of qualitative studies that does not involve generalization from a sample to a population for the measures on pre-determined variables. Rather, the inference is to a plausible mechanism for recognized cases of the phenomena of interest. For this reason, the key condition is the selection of the right kind of case and not the right number of cases since the latter will offer no measurable improvement in the probability of the conclusion (Yin, 2013). The unit of analysis is an IURV. Drawing on the description contained in Li et al. (2016), we define an IURV as an arrangement where a university establishes, or partners with, research facilities or specialized research offices outside its home country. We employed a standard protocol that specified case selection and interview questions.

The criteria for case selection were as follows: first, we focused on IURVs involving US universities as the home institution in the two countries that have the most IURVs. This selection was informed by a database constructed of 183 IURVs worldwide of more than 100 leading US research universities (Li et al., 2016). Of these US IURVs, the largest number were in China (42 IURVs), followed by Singapore with 10.

Table 1
Framework of IURV institutionalization.

Nominal characteristics	Fully established IURV	Supporting characteristics
• Multi-country senior researchers	• Venture director(s)	• Educational function
• Multiple joint research projects	• Administrative support	• Government grants, other resources
• Formal agreement describing roles and responsibilities related to research project	• Multi-year resource commitment for joint research projects on both sides	• Policy rationale
• Naming of research venture	• Target/agreed research areas	• Intellectual property mechanism
	• Formal mechanism for convening/exchanging participants	
	• Visibility to host and home institutions	
	• Performance review	

Adapted from Youtie et al. (2006).

Table 2
Case study interviews.

Case Study	Interviews	Type of Interviewee
CREATE Campus (SMART, BEARS)	10	CEO and Directors, Executive Director, Assistant Head, Associate Professors, Center Director, Research Director, Senior Officers
UMHS-PUHSC	3	Director for International Cooperation, Director, Assistant Director
LMDIC	4	Associate Professor, Director, Key Laboratory Manager, Key Laboratory Associate
TBSI	6	Director of Overseas R & D, Dean, Assistant to the Dean, Vice Dean, General Manager, Marketing Director

Note: CREATE = Campus for Research Excellence and Technological Enterprise, Singapore; SMART = Singapore-MIT Alliance for Research and Technology; BEARS = Berkeley Education Alliance for Research in Singapore; UMHS-PUHSC = University of Michigan Health System–Peking University Health Science Center; LMDIC = Luminescent Materials and Device International Collaboration, Guangzhou; TBSI = Tsinghua Berkeley Shenzhen Institute.

Second, these two countries also were observed to have varying policies to support IURVs. Singapore's policies stemmed from an explicit central government initiative (the CREATE campus program). In China, by contrast, policies to support IURVs were promoted at provincial and municipal government levels. While the Chinese central government offered broad frameworks (including through the 985 and 211 programs) to fund university advancement, it did not explicitly define the particulars of programs with international universities (Zhang et al., 2013). Thus, the selection of these two countries with the largest numbers of IURVs also gave us variation in policy-level approaches as well as focusing on countries with relatively larger numbers of IURVS with US universities. Third, we developed a full set of options by country for case selection. In the case of Singapore, of the ten universities from around the world participating in the CREATE program, we selected the two US university partners: the program with MIT (SMART) and Berkeley (BEARS). Communication with the program sponsor and the director provided us with interview subject contact information. For, China we performed document and website reviews of the 42 US IURVs. After further review, we sent emails and telephoned 20 institutes with the best contact information. Of these, ten agreed to meet with us. We did not discern any broad difference by region or size range of the institutes between the ones agreeing to an interview and those not agreeing. Fourth, we visited each of these ten IURV sites and selected three as being the most demonstrative of different ways of operating IURVs in China based on the scale of the IURV and source of funding. The resulting cases reported in detail here are:

1) Singapore-MIT Alliance for Research and Technology (SMART) − established in 2007 to foster interdisciplinary research between MIT and the National University of Singapore (NUS) and the Nanyang Technological University (NTU) in applied topical areas of economic import to Singapore.
2) Berkeley Education Alliance for Research in Singapore (BEARS) − created in 2012 to conduct research building efficiency and sustainability between the University of California (UC) Berkeley, NTU, and NUS.
3) University of Michigan Health System–Peking University Health Science Center (UMHS-PUHSC) − a joint institute set up in 2010 to conduct cooperative clinical research in targeted disease areas.
4) The Luminescent Materials and Device International Collaboration (LMDIC) between South China University of Technology and University of California at Santa Barbara (UCSB). Started formally in 2014 with a research focus on organic light emitting diodes.
5) Tsinghua Berkeley Shenzhen Institute (TBSI) between Tsinghua University and UC Berkeley − established in 2012 in the city of Shenzhen, China, to advance cross-disciplinary research and education in three targeted technology domains.

Four of the five cases fully meet the nominal institutionalization characteristics and the fifth partially meets these characteristics. SMART and BEARS follow formalized administrative approaches designated by the Singaporean government—including structure, leadership, limited liability company (LLC) organization, and designated researchers and interdisciplinary project areas—although they have some ability to customize their response to these requirements. UMHS and PUHSC came to a mutual agreement, crystalized in a Memorandum of Understanding, as to how to structure their collaboration, leadership, senior investigators, and project areas. TBSI also meets the nominal characteristics of an IURV based on the requirements and wishes of the Shenzhen municipal government in that it has a formal name, agreement, directors and co-directors, and project areas as represented by the three cross-disciplinary centers. The collaboration between UCSB and South China University of Technology was not named officially − we agreed to denote it as LMDIC after a discussion with the interview subject at South China University of Technology. The collaboration also lacked a contractual arrangement or specified project areas aside from the broad organic light emitting diode research theme but it did have designated senior investigators and an annual workshop. Thus, LMDIC met several of the nominal criteria for an IURV. This variation is appropriate, especially to capture investigator-to-investigator led IURVs such as LMDIC.

The case study data gathering process was multi-faceted. We gathered documents from the IURV website, government reports, and journal publications. We conducted one or more onsite visits in March 2016 (Singapore) and May 2016 (China) involving two-to-three researchers from our side, with one researcher primarily asking questions and the other capturing the information. Multiple interviews were conducted at the sites, including with key university research administrators, directors of the IURV, and individual IURV researchers (Table 2). We also toured the IURV and its research facilities, which enabled observation of operations by the interview team.

The interview protocol addressed the history and goals of the IURV, the nature of the relationship with the host institution, funding mechanism for the venture, main research areas of the venture, the nature of interactions between researchers of the two universities, methods or metrics used for evaluating the effectiveness of the venture, and benefits and risks. The protocol allowed for focusing questions to fit the interviewees' role. Questions about the evolution of the research content areas and specific projects and the dynamics of collaborative interactions were directed at Principal Investigators (PIs) familiar with the antecedents. Managers and administrators were asked about the specifics of the interactions between the home institution and their host institution, including organizational and logistical relationships. In Singapore, we additionally conducted interviews with policymakers at the sponsoring agency and other science and technology agencies. In China, we interviewed university international office administrators and informants familiar with the Shenzhen government's foreign university initiatives, and drew upon background insights with researchers, government and industry from interviews conducted in the prior year. These interviews provided information on the broader policy environments and framework for IURVs in the host countries and localities. Interview notes were coded to identify the categories of the institutionalization framework and their relation to mutual benefits and shared objectives.

The next section presents capsule accounts for each of the five IURV cases. This is followed by a cross-case analysis of the case studies.

4. US IURVs in Singapore

The Asian city-state of Singapore has dramatically improved its economic position through foreign direct investment and government economic planning (Huff, 1997). This growth has been associated with a transition to a more intensive knowledge-based economy (Wong and Singh, 2008), as evidenced by Singapore's seventh place ranking in the 2016 Global Innovation Index (Cornell University et al., 2016). It is a transition based in part on the expansion of Singapore's university sector (Poh, 2016). A major initiative to foster this expansion is Singapore's Global Schoolhouse Project (Tee Ng and Tan, 2010; Sidhu et al., 2011). This project aims to enhance Singapore's human capital by attracting international university faculty and students to the city-state. The project is focused on Singapore's two major universities: the National University of Singapore (NUS) − a 1980 merger of two older universities founded in the 1950s and 1960s, and Nanyang Technological University (NTU), which was formally designated as a university in 1991. Although other universities were subsequently founded, NUS and NTU are the most prominent Singaporean universities.

A key feature of the Global Schoolhouse Project is the attraction of internationally recognized universities and one of the mechanisms for accomplishing this goal is the Campus for Research Excellence and Technological Enterprise (CREATE). This is a program of the Singaporean government, approved in 2006 by the Research, Innovation and Enterprise Council of Singapore and managed by the National Research Foundation of Singapore (NRF).[1] CREATE operates a S$360 m ($261 m) research facility adjacent to the NUS University Town (UTown) campus. The core of the program is its partnership with ten designated international research universities in which each partner university receives approximately $100 m for research projects over a five-year renewable period, with the majority of this money going to researchers at Singaporean universities. The program is designed to develop an expanded base of scientific and technical human capital and to focus scholars with a global reputation to investigate research problems that are central to the Singapore's economic development.

This program had strong roots in relationships between the Singaporean government and particular, mostly US, universities. An earlier program between NTU and NUS with MIT was formed in 1998 after initial communications between the Deputy Prime Minister of Singapore and the MIT Dean of Engineering (Redmond, 2011). This collaboration initially involved engineering and life science education and research projects through the Singapore-MIT Alliance, but subsequently evolved into the program discussed below to enhance the development of domestic innovation (Pfotenhauer and Jasanoff, 2017). Georgia Tech's School of Industrial and Systems Engineering was approached by Singapore's Economic Development Board (EDB), leading to the founding of The Logistics Institute-Asia Pacific in 1998. This Institute was involved in establishing a master's degree program in logistics with funding from the EDB, which reduced the tuition cost associated with the degree, and undertaking research projects. The Institute was associated with the NUS Faculty of Engineering, but then moved to the NUS School of Business. Similar relationships were arranged with Duke University, Johns Hopkins University, and others. MIT and Berkeley are now two US universities that are among the ten CREATE university partners in Singapore. We discuss these two cases, and insights gained, below.

[1] This section draws on telephone interviews with the directors of the SMART and BEARS programs on February 16, 2016 and March 22, 2016; an in-person interview with a Georgia Tech faculty member on February 12, 2016; and on-site interviews with officials at the National Research Foundation of Singapore, NTU, Agency for Science, Technology and Research and faculty at NUS and NTU from March 28 to April 1, 2016. Exchange rate of 0.724 used to convert Singapore ($S) to US ($) dollars (based on International Monetary Fund annual exchange rate for 2016).

4.1. Singapore-MIT Alliance for Research and Technology

MIT operates through the Singapore-MIT Alliance for Research and Technology (SMART), which began in 2007 shortly after CREATE was approved. SMART is a formal IURV organized through a separate Limited Liability Corporation (LLC), as required by NRF. The first director was the chair of MIT's mechanical engineering school while the current director was previously an air force chief scientist in Singapore as well as a full professor and dean of undergraduate engineering at MIT. These positions are term-limited appointments from the outset, although having a manager from the home university with ties to the host country can assist with these transitions. From MIT's perspective, SMART is an institute-wide initiative which reports into the MIT Vice President of Research. SMART uses Interdisciplinary Research Groups (as do all the CREATE universities), with research performed in five research areas: healthcare, biosphere-atmosphere-ocean sensing and modeling, future urban mobility, infectious diseases, and low energy electronic systems. Most of the work is applied research. Several hundred personnel have been involved. Specific projects in the Interdisciplinary Research Groups come from partnerships between MIT and either NTU or NUS researchers who were at MIT or are in the same field. MIT, NTU and NUS researchers each work on specific projects under common topics. Program funding does not go to support faculty but to support doctoral and post-doctoral researchers, travel, and facilities and equipment. SMART has an Innovation Centre. This provides grants to researchers for the development of prototypes, proof-of-concept work and market strategies and links researcher to Singaporean mentors to provide commercialization guidance and contacts. The Innovation Centre is led by an Intellectual Property (IP) Coordinator who provides assistance with IP disclosure submissions. IP submission then go to the Singapore Technology Licensing Office.

We expected to find tensions concerning the central ownership of intellectual property by the Singapore Technology Licensing Office. This intellectual property requirement seemed a potentially onerous requirement for MIT researchers. We asked interview subjects about this requirement. Interview subjects explained that compliance occurred through maintaining the Singaporean stream of funding in a separate account, allocating graduate students and other resources solely to these projects, and reserving any intellectual property coming out of this research for the Singapore Technology Licensing Office. One respondent maintained that work associated with Singaporean funds tended to be more applied than research conducted through standard scientific grants, which facilitated designating resources accordingly. However, another respondent discussed how a Singaporean spin-off company had to reproduce what was done in the lab because the spin-off could not comply with the intellectual property requirement. In sum, this intellectual property ownership policy is a substantial requirement compared to what we have observed in other IURVs. Participating researchers have to devote efforts to accommodate the regulation (ostensibly, at least), although we did not find evidence to confirm that this approach results in more intellectual property in Singapore than would be the case without the requirement. On the other hand, the requirement checked a governmental administrative objective to secure (again, at least ostensible) benefits for Singapore for the public resources expended on attracting foreign university research to the country.

4.2. Berkeley Education Alliance for Research in Singapore

The Berkeley Education Alliance for Research in Singapore (BEARS) was established in 2012. BEARS created an independent corporate entity to receive and disburse a $95 m grant over five years. UC Berkeley receives $20 m and researchers at NTU and NUS get $75 m. BEARS created two research thrusts related to energy: Building Efficiency and Sustainability in the Tropics (SinBerBEST), and the Singapore-Berkeley Research Initiative for Sustainable Energy (SinBeRISE). These themes

were highlighted in the Singapore research roadmap. BEARS has had two directors, with directors required to be based in Singapore. Both have been senior engineering professors from UC Berkeley. Collaboration commonly occurs through Berkeley and NTU/NUS researchers sharing a post-doctoral researcher (who is not necessarily a Berkeley graduate). NTU has rented an apartment in Berkeley to facilitate the collaboration. Key performance indicators (KPIs) have been developed for BEARS by UC Berkeley in conjunction with the NRF, NUS, and NTU. The KPIs for BEARS are in the following areas: human capital (e.g., doctoral students, post-doctoral researchers, faculty positions), intellectual capital (e.g., invention disclosures, patent applications, publications), industry relevance (e.g., projects with industry, industry funding, spin-offs, commercialization, royalties and licensing revenue), and international awards and prizes (Hall, 2015).

We contemplated that the detailed specification of KPIs might be a limiting factor in the flexibly to manage research at BEARS. Typically, KPIs are metrics used to manage an organization from the perspective of efficiency, performance, and stability as well as the resources and activities used to achieve these outcomes (Marr et al., 2004; del-Rey-Chamorro et al., 2003; Bose, 2004). KPIs are linked to company-oriented methods such as the "balanced scorecard approach" to measuring intangible knowledge assets (such as human capital and organizational structure) as well as tangible financial outcomes (Sveiby, 1997; Nonaka and Takeuchi, 1995) and have been extended beyond the individual company to development of knowledge economies at the regional and national levels (Cooke, 2002; Shapira et al., 2006). These types of measures have also been applied to university research, but their application has been criticized not only for the methods and data used (Billaut et al., 2010), but also for the misplaced precision and incentives that can distort the university research mission (Hicks, 2012; Hicks et al., 2015). We asked interview subjects at the sponsoring agency and the US and Singaporean universities about the use of KPIs. We learned that although Singapore directly manages the CREATE program, the development and application of KPIs is up to the participating universities, in cooperation with the sponsoring agency. Moreover, the sponsor indicated that KPIs are not the sole factor in the renewal or non-renewal of partner universities. The ten partner universities have gone through the initial five-year and renewal five-year period without significant change, although CREATE is currently engaging with new universities and not renewing, for a third period, some of the existing partner universities. Still, an audit of BEARS noted that some of the KPIs were unable to be achieved in the timeframe of the program (such as commercial revenue and prizes) and the audit recommended that the program modify its KPIs such that they are narrower and more likely to lead to successful application. This audit poses the risk that the relationship could be vulnerable to poor quantitative performance on one of these indicators and confirms that KPIs have to be specified and interpreted with care.

4.3. Insights from CREATE case studies

The CREATE partner universities are subject to several program requirements that reflect the strong design and oversight of the program by the Singaporean government. All research areas must involve Singaporean university researchers and partner university researchers. Many of the Singaporean university researchers have had a prior relationship or at least prior knowledge of the foreign university research leads and in some cases, the researchers do their work in their local research environments rather than performing ongoing joint investigations across the globe. There is little collaboration among the foreign partner universities housed in CREATE, however, with nearly all partnerships involving bilateral links between the foreign university and the Singaporean universities. A key challenge is a one year residency requirement for any foreign researcher receiving funding through CREATE; six months of this requirement must be served concurrently with the remaining months spread over the five year period. Some of the partner universities have had difficulties in finding faculty members to participate because of the residency requirement but none have found it impossible. In addition, we learned from interviews that this residency requirement can place strain on the faculty members' home department, suggesting that most of these faculty members have sufficient seniority and tenure to withstand such tensions.

Overall, it appears that all partners in these IURVs benefit from the arrangements established through CREATE. Foreign universities gain through access to state-of-the-art buildings and research equipment, stable funding over a five-year renewable period, working on problems in their field that are relevant to this unique setting, and being associated with visible impacts as research findings and policy implications are implemented by national government officials who are involved in the program. Singapore gains in that the majority of the funds is expended on research within the country, by having researchers around the world working on their societal problems, and by having formal research relationships with prestigious universities from the US, Europe, Middle East, and Asia. The Singaporean government has designed the program to maximize capture of knowledge in the country by requiring a Singaporean LLC, establishing residency requirements, and managing to KPIs deemed relevant for national development.

As to the future of the program, Singaporean officials at the sponsoring agency indicate an ongoing need to attract foreign research despite the rising reputation of NTU and NUS. Indeed, one might expect NTU and NUS to contemplate setting up their own IURVs offshore, and to evolve more as hubs, rather than recipients, of international research. Our interview subjects indicated that they considered themselves peers of their partner universities at this point and questioned the ongoing need for the foreign university in their current role in the program. Yet, while life cycle effects could result in a reduction of the institutionalized position of research partnerships with foreign universities that would dramatically change the organization of such partnerships in Singapore, as yet we did not observe that the sponsor was moving in this direction. The argument that the country's small scale and limited own research pipeline necessitates international research collaboration remains an important one from the sponsor's perspective.

5. US IURVs in China

China has undergone rapid growth to become the second largest economy in the world. Along with this rapid growth, there has been a strengthening of R & D. Starting in the late 1990s, the Chinese government increased funding to universities through programs such as the 211 Program which is aimed at creating approximately 100 world leading universities in the 21st century. Initially more than $2 billion was allocated to these universities for expanding degree programs and establishing centers of research excellence. Another level of funding was provided to a smaller, elite level of Chinese universities through the 985 Program, to increase the global ranking of elite Chinese universities. At the same time, the China Scholarship Council fostered international exchange through government-funded scholarships, subsequently attracting these students to return to China through programs such as the Thousand Talents Program (Li, 2013). Parallel to the efforts of the central government, provincial and municipal governments with strong local economies, such as Shenzhen, have also been distributing money to build up the capacity of local universities. One of the initiatives of regional and local governments has been to attract foreign universities to establish campuses in these regions (Chen and Kenney, 2007).

Although China is one of the most prevalent location for IURVs (Li et al., 2016), IURVs in China are more decentralized, initiated either through an individual university or a local government initiatives. There is no explicit national policy to promote IURVs in China, despite the significant national government funding put into schemes to build world-class universities (e.g., 985, 211 programs) and to promote

international personnel exchange and joint research. There are efforts to attract foreign universities to locate as part of regional development strategies, notably in China's rapidly advancing eastern regions in cities such as Shenzhen, Suzhou, and Ningbo (Chen and Kenney, 2007). Attracted by China's sizable market, a large number of foreign education campuses have been established. Our attention, however, is focused primarily on IURVs, and we examine three examples of IURVs in China: one in Beijing, one in Guangzhou, and one in Shenzhen. The first two IURVs stem from university-originated initiatives while, for in the third, the city of Shenzhen play a role through its policy to promote university research.[2]

5.1. The University of Michigan and Peking University Health Science Center Joint Institute for Translational and Clinical Research

Peking University, through its Health Science Center in Beijing, established a partnership with the University of Michigan Medical School in 2010 (Kolars et al., 2017). The University of Michigan Health System–Peking University Health Science Center (UMHS-PUHSC) Joint Institute was established to develop clinical research capacity in Peking University, which is less established in China, and provide access to a large population for clinical study that is not available in the US. The collaboration arose from a Peking University alumna on the faculty at University of Michigan. After various delegations and visits, the two universities founded a translational medicine partnership. They signed a memorandum of understanding in 2010 to create the Joint Institute for Translational and Clinical Research. Each side of the partnership invested $7 million for the partnership, University of Michigan from discretionary research funds and Peking University from the Chinese government's 985 special funding for building up leading universities. The funding supports awards of up to $800,000 for two-year projects with joint participation of University of Michigan Medical School and Peking University Health Science Center researchers. Most of the projects include research exchanges ranging from several months to one year.

The partnership is led by co-directors from each university. The interviewees mentioned that a co-director structure helps to foster mutual participation between the partner universities. A core partnership platform has been established involving bioinformatics, institutional research review, and science collaboration. The latter was designed to facilitate cooperation through leadership videoconferences, proposal coordination, opportunities for visits and exchanges, and the program's annual symposium. Another key factor in the partnership has been participation of executive committees in bioinformatics plus the four thematic program areas of the Joint Institute: pulmonary, cardiovascular, liver and renal diseases. Prior to a proposal submission, researchers must submit an abstract for review by the executive committee in the relevant program area. Once the abstract receives approval, the proposal goes through peer-review, where it is ranked, comments are given, modifications are made, and final proposals are directed back to the executive committees for final decision-making. In terms of outcomes, 52 proposals were submitted from 2011 to 2015 of which 25 received funding (Kolars et al., 2017). Two of these projects received funding from the US National Institutes of Health totaling $3.3 million. The projects have led to peer-reviewed journal articles. The collaboration has involved 300 researchers from both institutions. The symposium, the location of which alternates between the two universities, usually involves 50 researchers traveling from the foreign to the host site.

We observed mutual complementarities in the partnership. Peking University Health Science Center offers large numbers of patients. The University of Michigan Medical School offers a strong analytical capacity and experience in clinical research. This capability has helped Peking University Health Science Center to build up its capacity in areas such as bioinformatics, clinical research methodologies, and exchanges to provide experiences in the US research culture.

We would expect these two universities to work well together because they have money designated for the effort and their research strengths are complementary. Yet, explicit efforts have been required to manage the relationship, and establish structures, routines, and communication mechanisms to coordinate research in part because of a lack of experience in institutionalized cooperative research structures on the Chinese side of the partnership. The partnership has put into place a management structure, and a research structure that parallels the biotechnology core platforms, including an institutional review board and process that is not as common in China as in the US, to address these institutionalization problems. Still, we observed tensions such as how to get researchers on the US side to actively participate in the research and exchange program and issues in communicating given the time zone differences.

5.2. Luminescent Materials and Device International Collaboration

The Luminescent Materials and Device International Collaboration (LMDIC) is a partnership of the State Key Laboratory of Luminescent Materials and Devices at South China University of Technology in Guangzhou and the University of California at Santa Barbara (UCSB). The joint center, started in 2014, was established to enhance knowledge about frontier topics in organic light emitting diode (OLED) research, which is a strong research area in China and provide improved research capacity through research exchanges of students and post-doctoral researchers.

The partnership stems from Nobel Prize winner Alan Heeger's hiring of now Professor Cao Yong as a post-doctoral researcher, whom Professor Heeger met while traveling to China in the 1980s.[3] Professor Yong was elected to the elected to the Chinese Academy of Science in 2001. The collaboration began in a formalized manner after the Luminescent Materials and Device research group at South China University of Technology was awarded the State Key Laboratory by the Chinese government in 2011. According to a university official at South China University of Technology, this enabled the group to become one of the two top-ranked groups in China in OLED research. For the collaboration with UCSB, each side has a co-director, but not a great deal more in terms of internal administrative structure. The co-director on the South China University of Technology side is appointed by a 14-member academic committee, with a majority from outside the university. Co-directors serve as liaisons with their universities, make strategic decisions, and are involved in planning the yearly workshops.

There are no formal memberships, though the Heeger laboratory usually comprises the participants from the Santa Barbara side and the State Key Laboratory on the South China University of Technology side. In a given year, about ten Santa Barbara researchers will visit the laboratory. Each side funds its own research, but South China University of Technology funds travel expenses for Santa Barbara researchers' yearly visits. The funds for the China side of the collaboration derive from special funding from Guangdong provincial government's Bureau for Foreign Experts for attracting talent. In 2015, this funding amounted to 900,000 RMB ($150,000). Since 2016, the allocation from the Bureau has continued and the university has matched this amount. This continuation is based in part on the Bureau for Foreign Experts' evaluation of the collaboration based on three kinds of metrics: (1) level of activity of personnel exchange in both directions, (2) ranking of

[2] This section draws on site visits and interviews in mid-2016 in Beijing (at Tsinghua University, Peking University, and the Chinese Academy of Sciences) and in Shenzhen and Guangzhou (at Tsinghua Berkeley Shenzhen Institute, Southern China University of Technology, Hong Kong University of Science and Technology, the University of Central Lancashire, and Georgia Institute of Technology).

[3] https://www.nobelprize.org/nobel_prizes/chemistry/laureates/2000/heeger-bio.html (Accessed 8 June 2016).

university/prestigious partners, (3) outcomes such as publications (although it is unclear whether these apply to the Key Laboratory or the IURV).

The LMDIC partnership emerged as an outgrowth of an individual level collaboration between two prominent scholars. However, because the relationship grew organically, it is problematic to impose an institutionalization structure on top of the relationship. Currently, much of the funding is coming from the Key Laboratory on the China side, but this source lacks the flexibility to provide funding to the US side. For this IURV to further develop, beyond the connection of the two scholars, we would expect to see funding sources targeted directly to the IURV. We understood that administrators recognized this point. Nonetheless, the collaboration continues despite minimal institutionalization characteristics and uncertainty as to the boundary between the Key Laboratory and the IURV.

5.3. Tsinghua − Berkeley Shenzhen Institute

The Tsinghua Berkeley Shenzhen Institute (TBSI) has been operating as a formal institute since 2014. The institute stems from a longstanding collaboration since 1979 between Beijing-based Tsinghua University and UC Berkeley. The earlier collaboration mostly involved personnel exchanges and collaborations among pairs of faculty at the two universities. In the 2008–2009 period, the two universities upgraded their partnership from a standard memorandum of understanding to an umbrella agreement that formalized the exchanges and expanded them into other areas. The Tsinghua Berkeley Shenzhen Institute formed the Joint Institute in Shenzhen with local government and other support. TBSI adds further variety to the understanding of an IURV because there is no Shenzhen-based university host, but it does involve a leading domestic Chinese university, albeit located in a different part of the country, along with a US university.

The Shenzhen municipal government provided $52 million for the buildings and scientific platform and laboratories, and the Tsinghua Education Foundation (N.A.) Inc. contributed $22 million over five years for student scholarships, faculty, and supporting staff to attract the two universities to locate research and education capabilities to Shenzhen. No cash contribution from UC Berkeley was expected (UC Berkeley Office of the President, 2015). The Shenzhen government provided this funding to build up its university sector in support of a more innovation-oriented economy because its strong manufacturing sector faces threats from rising labor costs and industrial relocation to lower cost locations in inland China. This money cannot be spent outside of China, so the institute raises money from alumni to cover Chinese visiting student and other research expenses in California. Still, UC Berkeley professors receive substantial funding when conducting research in Shenzhen.

The governance of the institute is led by a board chaired by the presidents of the two universities and the mayor of Shenzhen. There is an Industry Advisory Board comprised of 35 Chinese and foreign firms that provide input on fund raising and strategic issues. The institute also has an academic committee chaired by officials at each university and co-directors and co-associate directors in each cross-disciplinary field. The cross-disciplinary fields are arranged as centers that respond to local problems and enhance the capabilities of graduate students and post-doctoral researchers. Among the centers, there is one focused on environment science and energy including laboratories on nano energy materials, environmental science and technology, smart grid and renewable energy, intelligent transportation and logistics systems, and integrated policy modeling and low carbon economics. The theme of a second center is data science and information technology, including laboratories on sensors and microsystems, nano-devices, the Internet of Things, next generation Internet technologies, big data research, and computational photography and display. A third center targets precision medicine and health care, including laboratories on macromolecular platforms for translational medicine and bio-manufacturing, cancer biomarkers and therapeutics, biomedical detection and imaging, stem cell therapy and regenerative medicine, and integrated molecular diagnostic systems. Each center encompasses multiple academic departments, including applied technology and social science perspectives.

There are 44 core principal investigators (all tenured professors) in these centers: 16 from Berkeley and the rest from Tsinghua. All intellectual property coming out of the research performed in the institute is held jointly, with agreement of both sides required for license negotiations. Although both universities have a strong basic research orientation, there are complementarities in that the Tsinghua side has more of a technical implementation orientation while Berkeley has a strong fundamental science orientation. The institute also serves an education function. The institute admitted 31 PhD students in its first year and added a dual master's degree program, with Tsinghua focusing on technology and Berkeley on business and leadership. Measurement of performance, guided by faculty advice, is based on input indicators such as number of workshops, students, and research projects, rather than output measures such as publications and patents. The benefits of the institute include enhanced recognition, access to leading Chinese companies in the region, and funding by the local government for excellent research and teaching facilities. These benefits are mitigated by challenges in finding flexible funding and in securing administrative approvals from the respective home university campuses.

The merits of this approach lie in the setup of the formal structure in advance of the operation of the partnership. The design of the partnership reflects experience and knowledge. The structure uses thoughtful team-based approaches and co-administrators at all levels. While the formal structure is there, the substance of the research and teaching promised to the local government has ramped up slowly (including hiring only a small number of faculty a year). This pacing suggests that existing faculty from Tsinghua and possibly Berkeley have to shoulder progress toward metrics in the early years. There are risks in this type of IURV because it will require the parties − local government and two universities − to commit to nurturing this partnership over several years.

6. Cross-case analysis

A cross case analysis is carried out by applying the institutionalization categories of our hypothesized framework to the evidence from each case for establishing a specific institutionalization pattern and its relation to the realization of mutual benefit or the resource dependence (Table 3). Although the five selected cases embraced the nominal characteristics of institutionalization, the ways these cases acquired them and the specific combination of characteristics are not the same. The Singaporean cases acquired them from requirements of the central government's program. The UMHS-PUHSC obtained these characteristics by agreement of both parties. TBSI put these characteristics into place to respond to requirements of the Shenzhen local government. LMDIC evolved these characteristics over the course of the collaboration between two senior academicians. At the same time, we saw that each of the cases went beyond these nominal characteristics, taking different approaches to reaching their current IURV status. We extend these comparisons from the dimensions of our framework and discuss them below.

6.1. Characteristics of IURVs

6.1.1. Venture directors

Venture directors provide enabling leadership for the IURV. SMART and BEARS each have a single director from the US university. The key challenge is for this individual to have visibility and credibility to enable communications with both the Singaporean host and in their home university administrative organizations. In the case of SMART, the current director was a full professor and dean at MIT and had a prior

Table 3
Cross-case analysis of IURV institutionalization.

IURV Institutionalization Characteristics	SMART	BEARS	UMHS-PUHSC	LMDIC	TBSI
Nominal characteristics	Top-down	Top-down	Equal	Bottom-up	Localized
Venture directors	Formal director	Formal director	Formal co-directors	Informal co-directors	Formal co-directors
Administrative support	Very extensive, centralized	Extensive, decentralized	Adequate, partitioned	Minimal	Adequate
Target research areas	Government approved target areas; both sides equivalent	Government approved target areas; both sides equivalent	Four specific research areas	No project-specific targets	Three topic-oriented research centers
Personnel exchange	Residency requirement	Residency requirement, annual and mini symposiums	Large annual symposium	Annual workshop in China	Informal visits to China
Visibility	High level visibility, all partners	High level visibility, all partners	Visibility, all partners	Minimal visibility China partner	High level visibility, all partners
Resources	Five-year renewable from Singapore	Five-year renewable from Singapore	Each side provides funding	Funding from China	Funding from China
Governmental support	National, direct	National, direct	National (China), indirect	Provincial, supporting	Provincial, direct

research career at Singapore; these ties facilitate the transition from the initial director to the current one and enhance visibility with both partners. The other IURVs have co-directors from the China and US sides, splitting the function of relations with home and host universities. The benefit of co-directors is that it ensures that the partner universities are mutually involved with the research venture, it provides more visibility with the directors' primary university, and it offers a point of contact for liaison activities with partner IURV participants. In the case of LMDIC, their directors have dual roles, as heads of the laboratories at South China University of Technology and at UCSB also serving as de facto heads of the IURV. Although a single director provides accountability for the large scale, multi-university programs sponsored through the CREATE program, engaging co-directors is an effective approach when there are only two university partners, such as with the Chinese cases.

6.1.2. Administrative support

Administrative support is indispensable to day-to-day operations and dealing with the requirements of host institutions while at the same time meeting the requirements and standards of the home university. SMART and BEARS both have large administrative support staff who handle purchasing, hiring in the host country, tax issues, finances, operations, communications, information technology, events and programs, intellectual property and the like. The administrative staff in SMART is centrally available across all project areas. BEARS, in contrast, has placed some administrative capacity in each of the two main research areas to provide support for information technology, laboratory, and overall project needs. In both IURVs, all administrative staff are Singaporean. UMHS-PUHSC has three enabling cores—bioinformatics, Institutional Review Board, and collaborative science—for the four research project areas. UMHS and PUHSC each provide staff support for these enabling cores. TBSI has administrative staff in Shenzhen to handle communication, facilities, information technology, and other functions associated with operating the new facilities in Shenzhen. An exception is LMDIC, which does not have any designated administrative staff, although staff is available in either the collaborating labs or the respective universities.

6.1.3. Multi-year resource commitment

Multi-year resources provide stable funding to enable the IURV to build up its offerings through the life cycle stages depicted by Pfotenhauer et al. (2016) of conception, design, negotiation, implementation, and operation. SMART and BEARS have completed two five-year, $100 m renewal periods, most of which goes to the Singaporean university partners to conduct research. The Shenzhen government provided $52 m for operating funds over a five year period and facilities and equipment to be used in the region while neither Tsinghua nor Berkeley are required to put up cash (but Tsinghua did contribute an additional $22 m for study). LMDIC received 900,000 RMB from the provincial government, matched by the university to pay for travel. In the UMHS-PUHSC relationship, each university provided $7 million five-year funding for joint research projects, administrative cores, and travel for that particular university. Although this IURV does not receive a direct allocation of national or provincial government funds to support the collaboration, the partners may well have the most resource flexibility because each institution controls its own funding. This kind of multi-year support enables the programs to take a "long view" because they know they have the resources available. If these resources are withdrawn, however, the most fully institutionalized of these ventures may well not continue.

6.1.4. Target research areas

At the heart of an IURV is the collaborative research that involves the partner universities. SMART and BEARS each have designated research areas that are approved by the Singaporean government and that relate to Singaporean societal problems concerning urban mobility, energy use and sustainability, and tropical diseases and health care. These areas involve multiple disciplines, they have clearly defined names, and the individual projects associated with them are listed along with the researchers at the partner universities engaged in these research projects. UMHS-PUHSC works in four specified disease areas but the individual projects come from ideas of researchers at the two partner institutions and are not required to have, for example, the approval of the Chinese government, but rather are evaluated based on peer review of the Executive Committee, which is comprised of five members at each institution. TBSI has three cross-disciplinary research centers and 16 laboratories focused on research areas under these three centers. Researchers from the two partner universities are associated with each of these centers and laboratories, with some researchers associated with multiple laboratories. LMDIC is broadly targeted to OLED research, but it does not designate specific research areas for the IURV, rather joint work emerges organically out of the research done in the UCSB and South China University of Technology laboratories. In sum, three of the cases demonstrate explicit attention to cross-disciplinary work. All five have a rationale for target research area selection that relates to the social and economic needs of the host country.

6.1.5. Personnel convening and exchange

Scientific and technology human capital development is an important goal of research collaboration (Bozeman et al., 2001; Ponomariov and Boardman 2010). The extent of exchange can be directly considered as being based on time spent by home university researchers in the host country (and vice versa). The Singaporean IURVs must adhere to the government's one-year residency requirement,

which includes a six month of consecutive time in the country. In addition, Berkeley's SinBerBest has annual and mini symposiums to gather scholars together to present their research on building efficiency and sustainability and to develop future areas. TBSI is not subject to a formal government residency mandate, but because the Shenzhen funds must be spent locally, the partner institutions have agreed among themselves to a two month residency period in the city, although there are no special events associated with this period other than teaching by the core principal investigators. UMHS-PUHSC and LMDIC also do not have to adhere to a residency requirement. Both of these IURVs use annual workshops and researcher exchanges to strengthen interpersonal connections between the partner institutions. These annual workshops have, for the most part, been held at the Chinese partner institution, even though discussions about alternating workshop locations have occurred, and the Chinese partner institution often pays for most of the expenses associated with these workshops.

6.1.6. Visibility

IURVs can create tensions in the need for presence and visibility at both the home and the host institutions, as discussed in the literature on dual embeddedness (Shams and Huisman, 2016; Klerkx and Guimon, 2017). Residency requirements necessitate extensive time in the host country, which has the potential to put the demands of the home university for research, teaching and service at risk. Many of the IURVs address this tension by having high-level administrators from all major partners on advisory boards and in IURV leadership positions. For example, the SMART director is an MIT graduate but who formerly worked in Singapore. The director reports into the MIT Office of the Vice President for Research and SMART board members include faculty from MIT, NTU, NUS, and the CEO of NRF. BEARS has a governing board, half of whose members are nominated by Berkeley and the other half from NRF; the BEARS director is a distinguished professor of engineering at Berkeley who reports to the Dean of the College of Engineering at Berkeley and adheres to the residency requirement to be based in Singapore for a significant part of the year. TBSI's Governing Board has high-level visibility, chaired by the Chancellor of Berkeley, the President of Tsinghua University, and the mayor of Shenzhen and including three senior administrators from both universities. UMHS-PUHSC has visibility at the offices of the UMHS Dean and the PUHSC Vice President of Research in that the co-directors are the Senior Associate Dean of UMHS and the Vice President of Research at PUHSC. However, LMDIC has no formal visibility to UCSB and limited visibility with South China University of Technology's International Office, in that this office provides matching funds to the university laboratory. The presence of high-level officers from both institutions involved in most of these IURVs contributes to making the IURV visible to the central administrators of each university, although the extent of awareness about specific projects and regular operations is likely to vary.

6.1.7. Performance review

Performance reviews of university activities have spread widely since the UK's initial Research Assessment Exercise in 1986. Hicks (2012) notes that while these reviews fall under the auspices of national ministries responsible for education and research, they often draw on an explicit set of ex-post bibliometric metrics such as counts of papers, citations and journal rankings that are applied to the research unit level. The IURVs differ in how they reflect this orientation, with each varying in the attention and approach to the evaluation of their performance. SMART engages in performance reviews but does not apply a binding set of key performance indicators (KPIs). In some instances, deliverables are assessed based on the research itself, such as building a driverless vehicle with certain complex capabilities such as negotiating intersections. BEARS developed mutually agreed upon KPIs among Berkeley, NRF, NUS and NTU. An audit of the program suggested that these KPIs were too general and ambitious for the timeframe of the arrangement and needed to be more narrowly tied to the projects (Hall, 2015). UMHS-PUHSC is doing a self-study of its "science of collaboration" through interviews and document review. In addition, the venture is collecting conventional benchmarks such as number of projects funded, publications, and extramural support based on pilot funding from the institute. LMDIC collects three kinds of metrics: (1) level of activity of personnel exchange in both directions, (2) ranking of university partners, and (3) outcomes such as publications. These metrics are gathered primarily for requirements on the Chinese side associated with the Key Laboratory; there is no evidence that the University of California at Santa Barbara requires these metrics. TBSI has developed a more limited set of metrics focused on input indicators that the venture can affect directly, including number of workshops, students, and research projects.

6.1.8. Supporting characteristics

Examination of the resources for IURVs underscores the importance of host government support. The IURVs in Singapore are sustained by a national research program with an economic development rationale that encourages attention to important societal problems of Singapore through interdisciplinary collaborative applied research. The Singaporean IURVs are also backed by a strong intellectual property regime in which intellectual property is held by the Singapore Technology Licensing Office. IURVs in China benefit considerably from local government support. The Shenzhen city government financed TBSI to strengthen its university sector as part of the broader effort of the city to transition to an innovation-based sector in response to competition in manufacturing from lower cost rural areas of China. The Shenzhen government safeguards its economic development objectives through the mayor's role as a co-chair of the TSBI governing board. LMDIC received funding from the Guangdong provincial government's Bureau for Foreign Experts for attracting talent. Although the UMHS-PUHSC collaboration is self-funded, the $7 million from PUHSC was originally obtained from the Chinese national government's Project 985 for the development of globally renowned universities.

7. Discussion and conclusions

This paper has examined a category of university research collaborations that are institutionalized as IURVs. In our discussion and conclusions, we return to the research questions posed at the beginning of the paper and link the findings from the cases back to the conceptual framework and to broader implications.

7.1. Differences in mechanisms and institutional forms in the development of IURVs

The first two questions of the paper probe how IURVs develop into established institutions that conduct R & D and ask to what extent there are differences in the mechanisms and institutional forms in this developmental process. These two questions are intertwined. Our cases highlight variations in the path and nature of institutionalization and find differences in the features of the process that determine IURV forms and outcomes. Yet, there is an underlying pattern that sorts the cases, which is the combination of governance and the resulting rules of accountability and benefit distribution. There are two dimensions that allow classification of the observed outcomes (Table 4). The first is whether government is involved in the setting or rules for operation and benefit distribution. The second is the degree of control and planning (or structuring) of the IURV's governance arrangements. In three cases, government is directly involved and there are conditions for receiving government resources that shape the IURV. In two other cases, the government is not involved in the governance structure and the rules of institutionalization are set by the partners themselves. On the other hand, of the cases with government involvement, two (in Singapore) have much tighter control and planning arrangements than the third (in

Table 4
IURV institutionalization modes.

	Non-Government	Government
Loose structuring	*Non-government–contingent* LMDIC	*Government–facilitated* TBSI
Tight structuring	*Non-government–collegial* UMHS-PUHSC	*Government–directed* SMART; BEARS

China). Similarly, of those without government involvement, one has a structured system of project selection and planning and the other is more open to contingencies and opportunities assessed by the collaborators in an ongoing fashion.

In the two Singapore cases, the source of nominal institutionalization derived from the top-down requirements of the Singaporean government. As a result, the fully established IURVs in Singapore tended to have well-articulated centralized administration, clear government-approved targets, and stringent residency and intellectual property requirements, and they are subject to long-term planning and performance indicators. We denote this approach to institutionalization as *government-directed*. The research ventures are structured to ensure that the Singaporean government can appropriate the benefits of the IURVs through multiple institutionalization mechanisms. These include requiring US universities (and indeed all CREATE foreign university partners) to establish LLCs in Singapore, designate Singapore-based directors, conduct research targeted to Singapore's societal challenges and needs, adhere to foreign senior investigator residency requirements, involve researchers at NUS and NTU jointly in all CREATE-funded research projects, and manage intellectual property through the Singapore Technology Licensing Office. A directed IURV develops an institutionalization pattern that adapts to the requirements of the resource origin, subordinating other dimensions of benefits to the eligibility and performance requirements of the funders. The risk of dual embeddedness tensions would be expected to be higher from the perspective of the home university, in that the government-directed IURVs have to be sensitive to the host institutions' needs. Moreover, the question arises as to whether the scientific and reputational benefits are affected by this arrangement and whether there is a tradeoff that is acceptable for a price, given the considerable level of funding in the tens of millions of dollars.

In contrast, UMHS-PUHSC is a *non-government-collegial* IURV in which the rules of the game are determined and enforced jointly by the two partner institutions. The source of nominal institutionalization in this case is mutual agreement of both parties. Many of the characteristics of the fully established IURVs result from the sharing of power. This IURV has co-directors, and administrative support is partitioned. Targeted research areas only work where there are mutual interests or complementary areas. Personnel exchange is based largely on voluntary participation. Visibility exists because the scholars and their institutions themselves have prominence. Each institution also contributes resources to the IURV from general funding from their national governments. This pattern of institutionalization is clearly developed to realize a common scientific benefit, while the risk to the IURV is that it depends heavily on extent of active participation and leadership of each institution, where home-host institution tensions may be raised as a result of non-involvement of one of the parties.

LMDIC exemplifies what we call a *non-government–contingent* institutionalization pattern. This IURV has a low level of institutionalization relative to the other cases we profiled, but it is still enduring and has more complexity than a typical individual faculty international collaboration. The source of institutionalization is found in the routinizing and normalizing of research relationships by the partners. In a contingent IURV, administrative support is minimal and the leadership tends to be informal. There are no specific scientific projects that the IURV is required to pursue. Funding for the IURV comes indirectly from a mix of national sources for the national key laboratory and provincial funding for scholarly exchange. What keeps the IURV going is collaborations among renowned scholars. They put more effort into common substantive scientific pursuits and student training than in seeking broader visibility of the institutionalized venture. Important elements include trust and heightened familiarity among the participants obtained through the routinized ongoing engagements among participating students and researchers. This level of trust reduces the need for more administration and thus the cost of the venture. On the other hand, the risk lies in sustaining relationships into subsequent generations of participating scholars, which can lead to frictions between the partners, particularly when participation of one side of the relationship, more than the other side, diminishes.

The TBSI case is like the Singapore cases in that the institutionalization drivers stem from the government, but the government is regional and offers real estate advantages for setting up an IURV in the location with little direct concern for the details of the research operation. Hence, the institutionalization pattern is different. Similarities to the Singapore cases include having formal co-directors, adequate support, and research areas designated by the government. However, there are substantial differences. The two participating universities have a stronger position so that they are able in some circumstances to more favorably leverage their positions. The intellectual property requirements are more flexible, the performance metrics are more activity oriented, and the student support (e.g., full scholarships) is more generous. Thus, we think of this case as institutionalized but with greater flexibility and leverage, hence we term it a *government–facilitated* IURV model. In the case of TBSI, there is a combination of an adaptation to resource origin and mutual scientific benefit, which leaves both the host university and the foreign university in a symmetric position vis-à-vis the funding entity. Furthermore, the host university is not local to the region. The regional policy aims to attract top universities from other regions of China and not only foreign institutions. In that regard, the host university is also obligated to the regional policy's conditions in a similar manner to the foreign one, which places them on more equal footing with respect to frictions related to dual embeddedness. The risk of this model is that it is highly dependent on the commitment of the regional government, which is perhaps vulnerable to turnover of government officials. One caveat is that variations across the case studies selected in this paper are limited. These case studies were selected to focus on the most active countries with respect to IURVs. Nevertheless, two of the case studies are situated in Singapore and subject to the same administrative directives. Similarly, China is distinctive in that it is a large country marked by a combination of centralized and decentralized policies, initiatives, and resources. The ability to generalize from these case studies to institutionalization mechanisms in other countries is thusly limited. It is hoped that the taxonomy developed from this set of cases can be tested in other contexts.

The case studies suggested that there were variations in the degree of institutionalization: the method of institutional control sometimes deriving from national or regional government, while in other instances from partner approval and concurrence. In either case, institutionalization enables formal structures for research collaborations going forward. Differences in the mechanisms according to the looseness or tightness of the structure and extent of government control matter in how the IURV becomes institutionalized.

7.2. Institutionalization differences and consequences

The third question concerned the consequences of institutionalization. There is an underlying notion that a main consequence of institutionalization is that it helps to retain the knowledge produced by the IURV in the region as opposed to having it relocate back to the home university when the senior researcher is no longer part of the project. Indeed, it could be argued that local capacity building through

the retention of local knowledge and hiring of local researchers means that IURVs are not solely focused on cross-national collaboration. However, the paper shows that there are cross-national collaborations in project work and output, but specific arrangements differ as the need to balance research collaboration and resource access differ across the cases in this paper. For example, in both Singapore and Shenzhen, arrangements were made to help research outputs stay local. Through the use of a *directed* IURV model, the Singapore government retains all intellectual properties from CREATE; while through the use of a regional *facilitated* model, the city of Shenzhen allows Tsinghua and Berkeley to jointly hold any patents from TBSI.

An underlying issue is, to whom does the institutionalization of international research collaborations matter? We cannot ascertain whether knowledge has been retained over the long-term by the host country as a result of the institutionalized mechanisms of the IURVs studied here because all are still operational. Considering another benchmark, IURVs have been proposed as a method for building scientific and technical human capital (Pfotenhauer et al., 2016). Many of our interview subjects mentioned how the IURV provides the institutional support for developing human capital. The IURVs we profiled typically support junior researchers. One interview subject described the IURV as a "magnet for talent."

On the other hand, the preconception of an IURV involving a relationship between a prestigious US university and a nascent host institution, the "institution-building" model in the Pfotenhauer typology, does not strictly hold true in the five cases profiled in this paper. The reputational differences between the host universities and their US partners have narrowed in recent years. Tsinghua University, Peking University, and NUS are now listed in the top 100 of the Academic Ranking of World Universities, NTU is listed in the top 101–150, and South China University of Technology is listed in the top 201–300 ranks.[4] Although multiple factors account for the rise of non-US universities in world university rankings, IURVs have likely added a boost to their research prestige. NUS's ranking in the Academic Ranking of World Universities has risen from 102 to 151 in 2003 to 83 in 2016, while NTU moved from the 350 to 400 category in 2003 to the 101 to 150 category in 2016. Tsinghua University has jumped from the 200 to 250 category in 2003 to 58 in 2016, with Peking University rising from the 201 to 300 rank to 83 worldwide over the same period. In these cases, the gap in broad research power of the home and host universities of IURVs is shrinking, becoming more akin to what Pfotenhauer and colleagues term as a bilateral model. It is difficult to attribute this movement to an IURV program versus other efforts of the university. Additionally, the IURVs discussed in this paper are at different development cycles and differ in form and function. At the same time, it is possible that leading US universities perceive reductions in their own risks and gains to their global prestige by working with fast-rising if not highly-ranked foreign partner universities.

More likely, IURV relationships form robustly among researchers that are equal or near equal in general capability but have specific strengths that are distinct yet complementary. In the UMHS-PUHSC venture, the UMHS side brings bioinformatics and clinical research expertise; the PUHSC brings access to patients and clinical practices. LMDIC involves a highly capable Chinese laboratory ranked number two in China according to the manager we interviewed, while the US partner side brings information on frontier topics. In TBSI, both have strong capabilities relative to the three transdisciplinary areas targeted by the initiative, but, according to a deputy director, the Tsinghua side has more of a technical orientation and the Berkeley side is more oriented to fundamental science and business and social science. In these cases, the IURV represents an extension of division of labor already prevalent in conventional international scientific collaboration.

[4] Retrieved from http://www.shanghairanking.com/ARWU2016.html.

7.3. Policy implications

The fourth research question was about the broader implications for future international university research ventures. In addition to testing a conceptual framework, our research findings also discerned policy and research management insights. In particular, the research suggests two major pathways for future IURV performance improvement. In government-led situations, such as found in Singapore and Shenzhen, policies towards IURVs should ensure a focus on enhancing and expanding substantive applied research rather than adding more administrative requirements in areas such as intellectual property. Spillovers such as training students, promoting collaborations, and sharing results with domestic and foreign research organizations should be encouraged. In non-government-led cases, as in LMDIC and UMHS-PUHSC, IURVs may wish to reflect on the desirability of institutionalizing processes. These processes include professional staff, stable funding, and formal routines for collaboration. Management training, sharing of best practices, and greater professionalization of administrative support for research are among the ways such processes might be promoted.

In both concept and practice, institutionalization is not without limits. The institutionalization of research can have drawbacks. Bozeman (2015) tracks the growth in administrative burdens on university researchers; while some of these rules are useful, others crowd out the amount of time available for genuine research. For example, one director we interviewed said that he had to be careful to document separate lines of research associated with the IURV from other funding supporting his laboratory. These kinds of restrictions add a further layer of administrative responsibilities on top of these senior investigators' existing research, teaching, and other duties.

Nevertheless, if universities and governments aim to achieve ambitious research goals and to ensure benefits from the new knowledge, then institutionalized research structures are enabling forms. The IURVs we examined provided leadership, support mechanisms, multi-year funding, relevant research targets, researcher-to-researcher exchange, visibility, evaluation, and supporting characteristics to advance their agendas. More broadly, these cases sought to make progress through research toward solving social problems, creating new cohorts of researchers with enhanced capabilities, and using new knowledge to build economies. Progress on such grand challenges is likely to be accelerated if structured and larger-scale international research collaborations, including IURVs, are well designed and implemented. While this paper has established a conceptual framework and undertaken initial field study, there are many openings for further work to understand the form, function, operation, and contributions of IURVs.

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