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Technology and talent: capturing the role of universities in regional entrepreneurial ecosystems

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Abstract

Purpose – This paper describes the entrepreneurial ecosystems of three public research universities involved in the National Science Foundation (NSF) Midwest I-Corps TM (trademark symbol) Node. It presents a synthesis of programming, functional structure, commonly referenced university metrics and their limitations in measuring impact on commercialization and regional development.

Design/methodology/approach – Based on current literature, university data and discussions with entrepreneurship leaders at the University of Michigan/Ann Arbor, University of Illinois/Urbana Champaign and Purdue University, this paper provides an overview and analysis of entrepreneurial resources and education initiatives.

Findings – University contributions to entrepreneurial ecosystems can be described with respect to infrastructure and leadership, technology and talent and culture of innovation. Four main university entities are responsible for driving entrepreneurship initiatives. Identification of these entities, their respective activities and their outcomes allows us to propose a framework for analyzing and measuring university entrepreneurial ecosystem impact.

Practical implications – The paper describes the variety of university-based entrepreneurial initiatives believed to contribute to university entrepreneurial vibrancy and ultimately regional development. It identifies ecosystem stakeholders and provides a framework for examining their role and impact for continuous development.

Originality/value – The research complements prior reviews and empirical studies of university-wide entrepreneurial ecosystems by focusing on programming within and across institutions according to four dimensions (academic, research administration, technology transfer and community engagement) with respect to technology and talent development. It describes similarities across institutions and limitations associated with measuring impact. It provides a foundation for future empirical research related to the impact of NSF I-Corps and entrepreneurial programming in academic settings.

Keywords Education, Entrepreneurship, Commercialization, Ecosystem, Technology

Paper type Conceptual paper

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Introduction

The impact of technological innovation and globalization on economic development and job creation is being felt across the USA, resulting in growing interest in how to nurture and sustain regional entrepreneurial ecosystems (Isenberg, 2010a; Strangler and Bell-Masterson, 2015). Given the role public universities play in developing technological innovations and meeting the human capital needs of their regions, and society more generally, academic institutions have bolstered investments in complex networks of entities to support technology commercialization and entrepreneurship education (Belitski and Heron, 2017). These entities include entrepreneurship centers, technology transfer offices, business incubators, clubs and networking organizations designed to support student and faculty innovators interested in commercializing research and/or bringing products to market. Often, these initiatives also include the support and involvement of regional industry leaders, economic development professionals and state and local government.

The federal government has also encouraged universities to play a more active role in economic development by supporting policies and funding programs that support technology commercialization and entrepreneurship education. The 1982 Bayh-Dole Act is considered critical to spurring universities and government labs' involvement in technology commercialization, as it gave universities and government labs control of technology licensing from federally funded research. This led to the establishment of technology transfer offices, which act as the mechanism through which university commercialization takes place (Aldridge and Audretsch, 2011). More recently, the National Science Foundation (NSF) launched the NSF I-Corps Program, which has revisited the government's historical approach to investing in innovation and entrepreneurship, which was primarily through basic science and translational grants (Nnakwe *et al.*, 2017). The NSF I-Corps program, launched in 2012, takes investments in scientific discovery one step further by investing in education and network development for individual university researchers, with the expectation of realizing greater economic and societal returns (Huang-Saad *et al.*, 2016b; Nnakwe *et al.*, 2017). I-Corps has been a significant catalyst in raising awareness of the interconnectedness of "real world" environmental factors (i.e. beyond the university) necessary to support of faculty commercialization. A unique characteristic of I-Corps is that it requires substantial involvement from many university stakeholders, including non-academic experts, entrepreneurs, industry professionals, economic development professionals and state and local legislators.

NSF's deliberate investment in developing the technology and talent of university researchers, and associated professional networks, provides a unique opportunity to explore the complexities of university contributions to entrepreneurial ecosystems.

To date, university outcomes associated with I-Corps have been measured primarily in terms of technology transfer metrics and assumptions of how these impact regional entrepreneurial ecosystems. Despite strong buy-in for the movement to more "entrepreneurial universities" (Etzkowitz, 2003; Gibb and Hannon, 2006; O`Shea *et al.*, 2007), links between the numerous entrepreneurial activities and administrative structures both within and outside of universities have not been well explored. Further, the impact associated with the range of entrepreneurial activities that take place in the university are not clearly defined, which is representative of the field of academic entrepreneurship (Dickson *et al.*, 2008; Duval-Couetil, 2013; Garavan and Cinneide, 1994; Matlay, 2008; Pittaway *et al.*, 2009). Therefore, the contributions of various stakeholders have not been examined in-depth as university entrepreneurship initiatives proliferate, and this becomes more complex when attempting to measure impact at the university- and regional-ecosystem levels. A foundation for understanding the core entrepreneurial initiatives of universities in these complex and dynamic ecosystems is necessary to design effective

programs and deploy resources in a way that maximizes contributions to regional economies.

The purpose of this paper is to explore entrepreneurship programming at three institutions involved in NSF I-Corps to provide an understanding of the breadth of the initiatives and complexities of university-wide entrepreneurial ecosystems in practice, as well as dimensions through which we can analyze them. The paper is organized as follows. First, we provide a synthesis of the entrepreneurial ecosystem literature and the role of universities within. Second, we describe common metrics used by universities and economic development organizations to demonstrate economic or entrepreneurial impact. Third, we provide a snapshot of the current university-wide entrepreneurial ecosystems at three research universities involved in the NSF Midwest I-Corps Node. Finally, from this synthesis, we examine the need for new approaches to analyze and measure the contributions of universities to regional entrepreneurial ecosystems. The intent is to provide university administrators and regional development organizations with a lens through which to consider university contributions to regional entrepreneurship and economic development, while considering metrics to examine impact over the short and long term.

Literature review

Background

The term ecosystem originated from the field of biology and is defined as a system that includes living organisms and a physical environment functioning together as a whole (Rice *et al.*, 2014). Social science researchers began to use the term "ecosystem" as it appropriately describes the nature of and complex interaction of economic communities that operate based on the interaction of individuals, roles, infrastructure, organizations (business and government) and events (Moore, 1993; Benjamin *et al.*, 2004; Bloom and Dees, 2008). Valdez (1988) appears to be the first researcher to document the term entrepreneurial ecosystem in a paper presented at the Small Business Institute Director's Association conference in 1988. In this paper, he adapted the ecosystem model to entrepreneurship and developed a theoretical framework for understanding new business formation. This was achieved by examining the literature to identify the most cited entrepreneurial environmental factors (Table I).

Today, entrepreneurial ecosystem language has become widely adopted to represent sustained economic growth and well-being through policies and programs intended to support entrepreneurs (Auerswald, 2015; Strangler and Bell-Masterson, 2015). The activities and outcomes associated with these initiatives can vary widely from being a community-based marketing effort to focusing on attracting entrepreneurial activity to a region around a particular industry (Strangler and Bell-Masterson, 2015). The density, fluidity, connectivity and diversity associated with ecosystems is considered necessary to foster and sustain their vibrancy (Strangler and Bell-Masterson, 2015). The interconnectedness highlights the dynamic nature of entrepreneurial activity, emphasizing the interactions that take place and the needs and challenges of various stakeholders (Feld, 2012; Hechavarria *et al.*, 2012; Isenberg, 2011; Kassean *et al.*, 2015). Strangler and Bell-Masterson (2015) stressed that the components and interactions within entrepreneurial ecosystems differ greatly from one region to another, based on population density and availability of capital (e.g. Silicon Valley versus the Midwest).

Interest in entrepreneurial ecosystems has grown in recent years, bringing together several streams of research (Acs *et al.*, 2017). This growth is largely the result of policy makers seeking to cultivate more innovative and entrepreneurial communities to fuel today's innovation economy (Motoyama and Watkins, 2014). As interest grows and practitioners rush to put the elements believed to foster entrepreneurial activity into place, it is important to recognize that research lags behind practice, resulting in limited causal

Table I. Key factors in entrepreneurial ecosystems

Valdez entrepreneurial ecosystem (Valdez, 1988)	Neck *et al.* entrepreneurial system view (Neck *et al.*, 2004)	Isenberg entrepreneurship ecosystem strategy (Isenberg, 2010a, 2011)	Stam entrepreneurial ecosystem (Stam, 2015)	World economic forum entrepreneurial ecosystem (World Economic Forum, 2013)
Venture capital availability	Incubator organizations	Conducive culture	Leadership	Accessible markets
Presence of experienced entrepreneurs	Informal networks	Enabling policies and leadership	Intermediaries	*Human capital/workforce*
Technically skilled labor force	University	Appropriate finance	Network density	Funding and finance
Accessibility of suppliers	Government	*Quality human capital*	Government	Support systems/mentors
Accessibility of customers	Support services	Venture-friendly markets for products	*Talent*	*Education and training*
Favorable governmental policies	Capital sources	Institutional and infrastructure support	Support services	*Major universities as catalysts*
Proximity of universities	*Talent pool*		Engagement	Cultural support
Availability of land or facilities	Large corporations		Companies	
Accessibility to transportation	Physical infrastructure		Capital	
Receptive population	Culture			
Availability of supporting services				
Attractive living conditions				

evidence-based practice (Stam, 2015). This is because the field lacks conceptual frameworks for exploring the cause and effect of entrepreneurial ecosystems and their components (Borissenko and Boschma, 2017), the breadth of academic fields exploring ecosystems has resulted in a varied terminology (Kuratko *et al.*, 2017), and inconsistent units of measure are used (Belitski and Heron, 2017).

Entrepreneurial ecosystem research

Historically, academic research associated with entrepreneurial ecosystems stems from two different bodies of work: regional development and strategy (Acs *et al.*, 2017). Both bodies of literature are retrospective in search of reasons why there are different outcomes for different communities. The regional development literature, typically housed in the academic field of economics, takes a broad view and explores differences in socioeconomic performances as a result of regional industries' influences on innovativeness, productivity or employment (Acs *et al.*, 2017). In contrast, the business strategy literature, housed in the academic field of management, is more focused and looks at individual firms and their coordination with economic partners to create value (Acs *et al.*, 2017).

A distinguishing feature of entrepreneurial ecosystem research is the focus on individual entrepreneurs and their interactions with their entrepreneurial environment to gain insight into business formation (Valdez, 1988). Most scholarship focuses on identifying common environmental factors, are more descriptive (Gnyawali and Fogel, 1994) and based on in-depth case studies of entrepreneurial ecosystems that have been deemed entrepreneurial (Cohen, 2006; Neck *et al.*, 2004). However, in 2004, Neck *et al.* recognized that simply replicating environmental factors was not sufficient to understand entrepreneurial ecosystems, given that entrepreneurship is complex and highly dependent on (the) interactions of the numerous stakeholders involved (Neck *et al.*, 2004). Through in-depth interviews of firm founders in Boulder County (Colorado), Neck *et al.* confirmed the role of entrepreneurial environmental factors previously found in the literature and began to explore the relationships between founders, incubators and spin-offs. Later, Isenberg (2010a, 2011) bridged research with practice by defining a roadmap for communities wishing to develop entrepreneurial ecosystems. While these factors have become a more accepted part of policy and practice, as demonstrated by the World Economic Forum's framing of entrepreneurial ecosystems (World Economic Forum, 2013), Stam (2015) reminded the research community that causality is still unclear.

Although the literature is fragmented (Gnyawali and Fogel, 1994) and terminology and classification schemes may differ, there is general agreement among scholars that entrepreneurial ecosystems share several common environmental factors such as leadership, support organizations, capital and human capital (Table I). Universities are commonly recognized as significant contributors to entrepreneurial ecosystems because of knowledge spillover (Audretsch *et al.*, 2012), meaning that knowledge produced through scientific discovery creates opportunities to be identified and exploited by entrepreneurs. As shown in Table I, human capital or talent is also a factor that scholars have identified to being significant to the vibrancy of entrepreneurial ecosystems. Therefore, given the tremendous resources they harness, universities play a significant role in cultivating, through education and training, the human talent that is eventually responsible for creating and commercializing technological innovations.

The role of universities in entrepreneurial ecosystems

Within the entrepreneurial ecosystem research (Audretsch *et al.*, 2012), a sub-discipline related to universities has begun to gain momentum (Guerrero and Urbano, 2012;

Guerrero *et al.*, 2016; Etzkowitz *et al.*, 2000). A more fluid connection between university innovators and communities is increasingly seen as a critical aspect of supporting driving university entrepreneurship and commercialization (Belitski and Heron, 2017; Isenberg, 2010b) and economic development. These connections are viewed as mechanisms for bringing commercialization knowledge to early stage academic research and the faculty and students who pursue such research (Caiazza *et al.*, 2012).

In 2007, Rothaermel *et al.* (Rothaermel *et al.*, 2007) sought to establish a taxonomy for the rapidly expanding, yet fragmented literature on university entrepreneurship. The authors reviewed 173 articles published in academic journals focused on university entrepreneurs, using keywords such university, entrepreneur, academia, technology transfer, science park and incubator. The review identified four fundamental themes focused on contributing to economic development through the commercialization of research:

(1) the [concept of] the entrepreneurial research university;

(2) examining the productivity of technology transfer offices;

(3) outcomes related to new firm creation; and

(4) understanding the environmental context including networks of innovation.

The first theme explores the overarching design of universities to support commercialization, while the remaining three focus on different units of analyses.

However, Rothaermel *et al.*'s literature review did not specifically identify the role of education and training. This could be a function of when the authors' work was published, or their desired focus. More recent publications by Morris and Kuratko (Morris and Kuratko, 2014) and Huang-Saad *et al.* (2016a) explicitly identified the contributions of education and training initiatives (Table II). Rothaermel *et al.*'s review was published in 2007, when entrepreneurship education targeting scientists, or non-business students more generally, was still fairly nascent. Since that time, administrators and researchers have acknowledged that an important dimension of university-wide entrepreneurial ecosystems is education (Audretsch *et al.*, 2012; Belitski and Heron, 2017). More than likely, these additions reflect the recent emphasis on connecting education to commercialization outcomes (Boh *et al.*, 2015)

Building blocks for university-wide entrepreneurial ecosystem (Morris and Kuratko, 2014)	Entrepreneurial research university (Rothaermel *et al.*, 2007)	U-M entrepreneurial ecosystem (Huang-Saad *et al.*, 2016b)
Interdisciplinary research	Incentive system	Infrastructure/mentorship
A curriculum and degree program	Status	Leadership support
Co-curricular programming	Technology	Education and training
Community engagement	Defined Role and identity	Financing
University operations	Culture	Culture of innovation
	Policy	
	Government policies	
	Faculty	
	Location	
	Industry condition	
	Intermediary agents	
	Experience	

Table II.
University-wide entrepreneurial ecosystem dimensions

and the growth of university entrepreneurship curriculum (Wasley, 2008). Huang-Saad *et al.* also introduced the need for internal and external funding to support both technology commercialization and education initiatives.

Similar to what appears in the general entrepreneurial ecosystem literature, university-based research is generally limited to descriptive case studies of university environments and practices (Miller and Acs, 2017; O`Shea *et al.*, 2007; Rice *et al.*, 2014), with limited investigation of interrelationships between environmental factors (Guerrero and Urbano, 2012), or guidance on assessment and evaluation, which could help direct practice. This is not surprising given the fact that universities are complex, heterogeneous organizations accountable to numerous stakeholders, such as students, alumni, faculty, staff to local citizens, communities and legislators. As such, it is difficult to research causality of entrepreneurial ecosystem design to outcomes and/or compare this across institutions, particularly over time.

Metrics used for measuring entrepreneurial impact

To date, the impact of universities on regional development is commonly associated with technology transfer activities. The Baye-Dole Act led to significant growth in university technology transfer offices to support commercialization and licensing (Thursby and Thursby, 2007). Each year, technology transfer offices report institutional commercialization metrics to the Association of University Technology Managers (www.autm.net/advocacy-topics/newsroom/fy2015-licensing-survey/). These metrics are used to demonstrate contributions to regional entrepreneurial ecosystems at the institutional level and include number of disclosures, patents, business start-ups and licensing agreements and licensing revenue. Example technology transfer metrics reported by the three Midwest NSF I-Corps Research Universities are presented in Table III. Often, these are published in annual reports aimed at university stakeholders to demonstrate:

- return on investment of research activity; and
- evidence of regional economic contributions.

It can be difficult to assess performance across institutions according to these metrics, as they can differ based on the nature of the academic disciplines represented at particular universities (e.g. the presence of a medical school), very proactive versus passive approaches to mining technologies for commercialization and licensing and the staffing levels and experience of commercialization professionals.

A significant limitation of technology transfer and economic metrics, in their current form, is that they cannot be related back to specific dimensions or initiatives deemed critical for successful university entrepreneurial ecosystems. As a result, it is unclear what drives these metrics and/or what specific aspects of university technology commercialization activities (e.g. investments in discovery, commercialization, business development and education) are most impactful. A recent study by Kolympiris and Klein puts into question long-held assumptions related to what drives commercialization outcomes (Kolympiris and Klein, 2017). In a study of 55,919 patents granted to research-intensive universities in the USA in 1969-2012, they found that the presence of a university business incubator actually decreased the quality of university innovations as measured by licensing income. Based on these surprising results, they encourage the research community to look beyond economic outputs in isolation and instead examine secondary outcomes that can be more valuable to universities and their regions.

Technology transfer metrics	2013	2014	2015	2016
U-M				
Invention disclosure	420	440	422	428
Patents awarded	128	132	160	135
License/option agreement	110	150	164	173
License revenues	$15.0m	$22.0m	$78.8m	$23.0m
Business startup	9	14	19	12
UIUC				
Invention disclosure	181	178	204	239
Patents awarded	72	78	76	73
License/option agreement	46	38	32	44
License revenues	$4.9m	$5.3m	$6.2m	4.85m
Business startup	6	6	10	11
Purdue				
Invention disclosure	294	272	303	356
Patents awarded	66	100	122	118
License/option agreement	87	120	131	147
License revenues	$8.0m	$9.1m	$8.13m	$6.6m
Business startup	8	24	25	27

Notes: U-M: UMOR Research Annual Reports (2013-2016); Purdue: Office of Technology Commercialization Metrics Report 2017; UIUC: Fiscal 2016 Annual Report from Office of Technology Management

Table III.
Technology transfer metrics by institution

Measuring university contributions to regional development

There have been more recent efforts to develop metrics for regional entrepreneurial ecosystems (Strangler and Bell-Masterson, 2015; White *et al.*, 2016) to guide communities interested in cultivating entrepreneurship and measuring the impact. Recognizing that communities have a tendency to focus on entrepreneurial "inputs" (e.g. research funding, capital and numbers of engineering degrees), Strangler and Bell-Masterson (2015) proposed output metrics to measure entrepreneurial vibrancy. These include four primary ecosystem indicators: density, fluidity, connectivity and diversity. Strangler and Bell-Masterson defined three measures for each indicator and suggested possible sources of data for each measure that should be tracked over time, not in isolation.

White *et al.* (2016) put these measures into practice in the context of the Tampa Bay Entrepreneurial Ecosystem (White *et al.*, 2016). In their model, they conceptualized the Tampa Bay Entrepreneurial Ecosystem in terms of three components: the community, the system and outcomes. In White *et al.*'s model, the four entrepreneurial ecosystem vibrancy indicators are embedded in the "system." White *et al.* also include two additional indicators: vibrancy and redundancy. While Strangler and Bell-Masterson referred to density, fluidity, connectivity and diversity as indicators of vibrancy, White *et al.* treat them as individual system indicators and include vibrancy as its own indicator and define it as the "vibe, positive energy, and unique culture of a region that leads to the creation of a robust entrepreneurial environment." In this model, redundancy refers to the redundancy of resources.

These approaches offer base-line entrepreneurial ecosystem measures for long-term regional entrepreneurship and propose new indicators that should be researched further for relevance. However, they also rely on a wide range of economic indicators and data that are resource-intensive to gather, particularly over time. While not directly transferable to

university-wide entrepreneurial ecosystems, the indicators and models offer a first step for envisioning ways to frame and capture university entrepreneurial outcomes.

Three university entrepreneurial ecosystems involved in I-Corps

In January 2017, University of Michigan-Ann Arbor (U-M), University of Illinois - Urbana Champaign (UIUC), Purdue University (Purdue) and University of Toledo were awarded a grant from the National Science Foundation to create the Midwest I-Corps Node. According to NSF, Nodes are "designed to support regional needs for innovation education, infrastructure and research" and are intended to "work cooperatively to build, utilize and sustain a national innovation ecosystem that further enhances the development of technologies, products and processes that benefit society" (Source: www.nsf.gov/news/special_reports/i-corps/nodes.jsp). This manuscript focuses on the three Research 1 universities involved in the initiative (U-M, UIUC and Purdue), all of which had already been involved in previous I-Corps programming.

U-M was one of the first of two universities awarded an NSF I-Corps grant in 2012 and were tasked with launching regional entrepreneurship training programs leveraging the I-Corps curriculum and support instruction in the national I-Corps program (Huang-Saad *et al.*, 2016b). Purdue and UIUC were awarded I-Corps Sites grants (2015 and 2013, respectively) (Nnakwe *et al.*, 2017) to create, develop and nurture academic entrepreneurial teams that could progress to the national I-Corps program. As of fiscal year 2017, there were eight I-Corps Nodes and 67 I-Corps Sites geographically dispersed across the USA. All I-Corps programs, national and regional sites, leverage the "Lean Launch" curriculum based on the "business model canvas" (Osterwalder and Pigneur, 2010) and the concept of "customer discovery" (Blank and Dorf, 2012). The training is based on the premise that scientists must emerge from their labs and actively engage in soliciting customer feedback to evaluate potential commercial opportunities.

In-depth interviews with university faculty and staff involved in the Midwest I-Corps universities indicated that university entrepreneurial ecosystems can be described with respect to ecosystem infrastructure, technology and talent and culture of innovation. However, university entrepreneurial ecosystems are complex, given the number of entities and stakeholders involved in the various aspects of technology commercialization and entrepreneurship education activity. Numerous administrative entities and stakeholders, both within and outside of the universities, are involved in entrepreneurship programming to develop university technology and talent that necessitate institutional organizational changes that promote an overall culture of innovation.

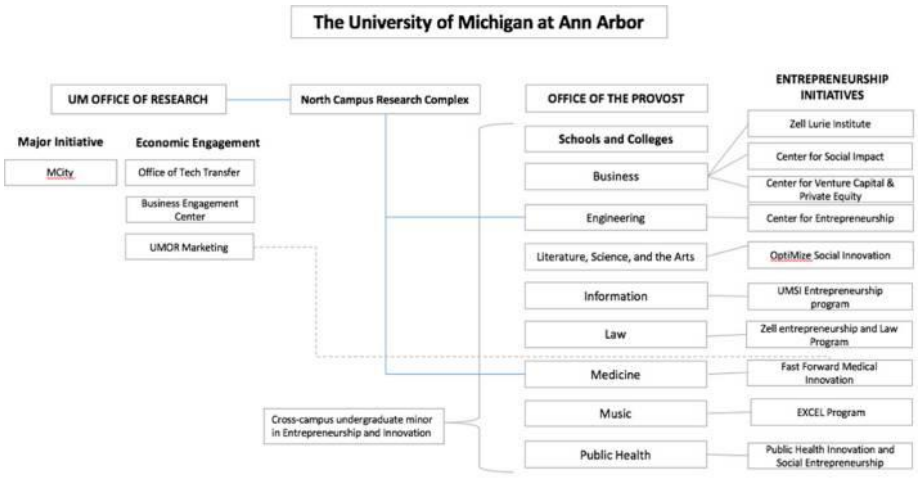
Ecosystem infrastructure

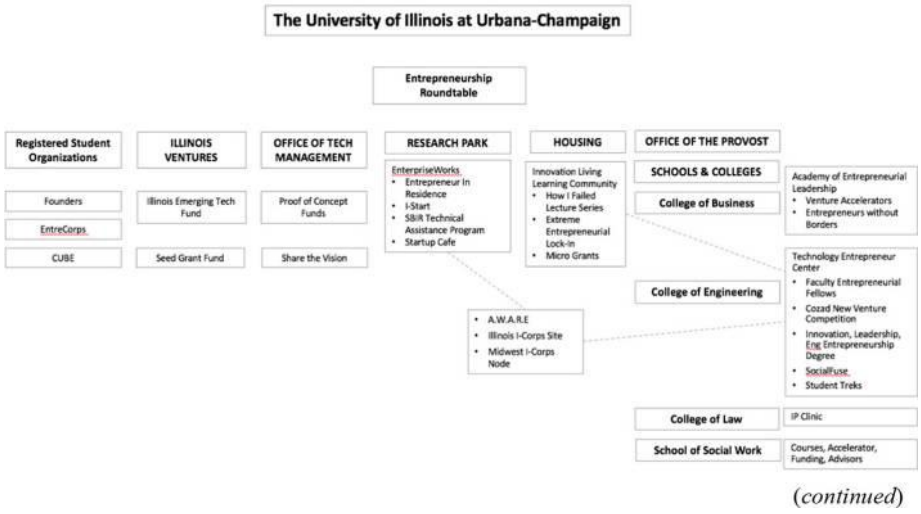
Entrepreneurial initiatives at U-M, UIUC and Purdue, Figure 1, show that each institution has a comprehensive, university-wide entrepreneurial ecosystem, in addition to their involvement in I-Corps.

Diagrams of these ecosystems depict the wide range of administrative entities and stakeholders, both within and outside of the universities, involved in entrepreneurship programming related to both technology and talent development. This includes the executive administrative levels (president, provost and vice presidents) to smaller academic or non-academic units. As the diagrams show, functional, collaborative relationships can span individual units, bridge academic and non-academic units and involve varying levels of cooperation non-university entities (Appendix 1). Broadly speaking, the initiatives at all three institutions fall into four different institutional entities, one academic and three traditionally non-academic entities:

(1) academic entities focused on education (offices of the provost, individual colleges and departments);
(2) research administration entities (management of sponsored research, industry relations);
(3) technology transfer entities (intellectual property, licensing and startup activity); and
(4) community engagement entities (incubators, accelerators, and co-working spaces).

These entities are frequently collaborative, with overlapping functions.





(*continued*)

Figure 1.
Organizational diagrams of university-wide entrepreneurial ecosystems at U-M, UIUC and Purdue

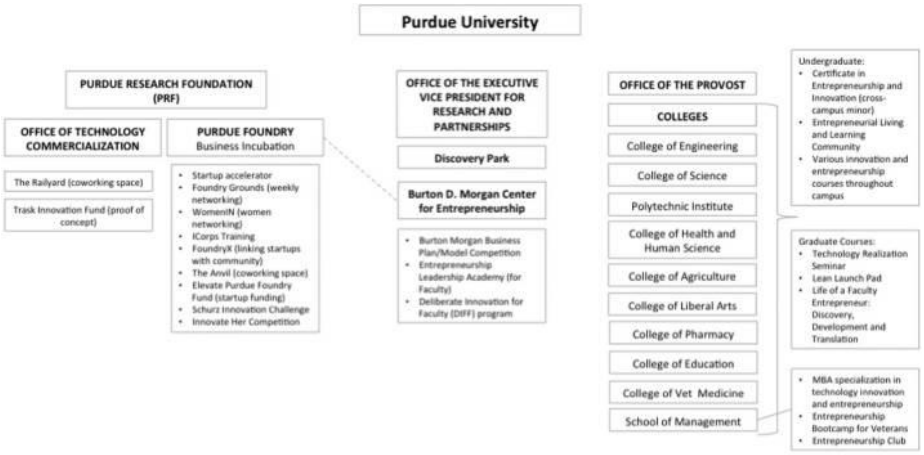


Figure 1.

Note: These figures represent only major entrepreneurship initiatives and entities across the institutions

There are significant challenges and limitations associated with capturing university ecosystem initiatives (programs, entities and collaboration) in one figure. For example, these diagrams do not represent the relative size (number of participants and level of funding) or impact of each initiative (outcomes post-program). It is also difficult to capture the dynamic nature of university entrepreneurship programming, given that these diagrams present only well-established initiatives, partnerships and units at one particular point in time when this article was finalized (December 2017). Nevertheless, they have value in that they document the breadth of entrepreneurial activities occurring at public universities today. The exercise of creating these diagrams provided a glimpse into the many challenges associated with assessing their individual and collective contributions to talent development, technology development and any resultant regional entrepreneurial ecosystem vibrancy.

Technology and talent

It is critical to understand organizational infrastructure to develop hypotheses about contributions of various initiatives to university level or regional entrepreneurial ecosystems and to create frameworks through which to analyze them. From the organizational diagrams, it is evident that there are two primary outcomes of university-affiliated activities: technology and talent development. Technology development refers to activities and resources that assist in moving scientific discovery to the marketplace. Talent development addresses any education and training initiative designed to prepare individuals for entrepreneurial activity. These findings are consistent with the historical context of universities. Initially created to develop talent, over the years, universities' missions expanded to include research, development (Etzkowitz, 2003) and commercialization. Traditionally viewed as separate missions, the growing importance of scientific discovery in today's innovation economy has fostered efforts to cross-fertilize these missions. One such example is the creation of the NSF I-Corps program.

University technology development involves non-academic, university foundation or research administration activities that support for-profit activities that stimulate technology

commercialization. This includes physical spaces (e.g. research parks, technology parks and co-working spaces); intellectual property support (e.g. protection and licensing); startup support (e.g. incubators and mentoring programs); and financing support (e.g. competitions, seed funds and access to investors). Often, these units/activities function as a middle ground between academic institutions and the community. Policies and practices affiliated with these entities can play an important role in shaping the entrepreneurial culture at universities (i.e. IP policies). Investments in infrastructure demonstrate a financial commitment on the part of universities to regional entrepreneurial ecosystems. Regular communication and engagement with a wide variety of stakeholders from the business community, alumni and policy makers reinforce this. In addition, universities provide various kinds of entrepreneurship-related funding to students, faculty and community members, the goal of which is to provide seed capital available to investment-worthy startups, increase the commercialization of intellectual property (IP) and/or support university missions to serve their states. This funding is obtained from many sources, from individual university donors to state government entities (Appendix 2).

Talent development represents significant investments in entrepreneurship education and training for undergraduate students, graduate students and faculty across disciplines, as well as community members. These educational opportunities not only include academic classes (credit-granting) but also engage community partners by workshops and seminars (non-credit-granting). Several academic units provide technology commercialization knowledge and training for university and local community startups or targeted groups (e.g. women and veterans) to help them enhance their knowledge of commercialization, startups and funding. Table IV shows examples of the broad range of academic initiatives offered to the university and local communities.

Culture of innovation

In addition to putting programming in place, universities seek to foster a culture of innovation – on campus and in their regions. This requires a deliberate organizational change process to promote campus-wide efforts to create an environment where innovation is encouraged, inspired and admired at the community level. This includes modifications to university IP policies, licensing arrangements, criteria for tenure and promotion, as well as increased public relations, celebration of innovation outcomes and university-community engagement.

Policies at many universities are changing rapidly to address academic entrepreneurship and innovation. There has a nationwide movement to streamline IP policy and practice and licensing agreements. Significant efforts are being made across institutions to make commercialization activity more user/stakeholder-friendly so that more faculty will participate. For example, today, it is a common practice to allow students to own the IP they develop as part of classes or competitions as a means to foster student innovation (Pilz, 2012; Weilerstein and Duval-Couetil, 2016). University tenure and promotion policies are also changing to recognize technology commercialization activity as scholarly work. Given that faculty motivation is fundamentally driven by the tenure and promotion policy (Office of Innovation and Entrepreneurship, 2013), some universities are recognizing these activities either within individual academic units or across campus.

Significant efforts have been made to promote innovation across campus through non-academic programs, offering a means of cross-fertilization across disciplines, units and academic programs. Faculty innovation awards are commonly used to highlight successes and promote more faculty awareness and involvement. Student-driven organizations and activities have become responsible for the movement of ideas across

Participants	Academic initiatives examples	Descriptions
Students	Individual entrepreneurship courses (undergraduate and graduate)	Once only offered through business schools, entrepreneurship courses are found across the university curriculum. These range from courses focused on entrepreneurship fundamentals, to more specialized courses focused on creativity or IP. Practicum classes offer students credit for working on their own startups or for interning with startup companies
	Undergraduate minors or certificates	Universities offer different forms of transcripted credentials for students, which are campus-wide or driven by individual academic units. These require enrollment in a series of credit-bearing entrepreneurship courses while completing their degrees
	Entrepreneurship Master's programs	Master's level entrepreneurship courses and programs in business schools are either tracks within current MBA curriculum, or offered as part of a dual technical-entrepreneurship programs. Whereas the MBA entrepreneurship tracks are grounded in business principles and agnostic to the focus of an entrepreneurial venture, dual technical-entrepreneurship master's programs look to integrate technical development and opportunity identification with business
Faculty and student researchers	Graduate courses focused on technology commercialization	Graduate courses have been developed that target graduate students and faculty in STEM disciplines specifically. These expose scientists to the commercialization process, and how it applies to their research to better prepare them for licensing and startup activity
	I-Corps training	Midwest I-Corps actively involves faculty and graduate students in the process of translating research into commercial technology. Three different levels of the program are offered: Introduction to Customer Discovery course (4 weeks long) focused on developing value propositions and customer segments, Industry-Focused I-Corps offers resources and mentoring for faculty who have already discovered a market fit for their product, and National NSF I-Corps (7 weeks long) focused on extensive customer discovery to identify markets, customers, and commercial value
	Entrepreneurship seminars or leadership programs	Seminars directed at entrepreneurial faculty support the development of technologies, academic courses or scholarly ventures. Cohort-building programs are designed to share knowledge, resources, and create networks of entrepreneurial-inclined faculty
Community	Entrepreneurship programs and workshops for targeted groups	Programs targeting specific groups from the community can take the form of in-residence programs, networking events, and workshops or seminars. These involve a number of campus and community entities. Groups targeted include veterans and under-represented populations
	Executive Education	Business school faculty offer intensive entrepreneurship training to individuals and companies

Table IV.
Examples of academic initiatives at Midwest universities

programs and schools. Student experiences and enthusiasm are major drivers of campus culture through events such as hackathons, startup weekends and use of co-working and maker spaces. They also support faculty research and commercialization activity by participating in research and internship experiences. University marketing departments are also playing a role in internally and externally promoting technology commercialization. This communication and outreach can contribute to recruiting students and faculty to the institution, inspiring them to participate in entrepreneurial activity, while simultaneously gaining the support of alumni and policymakers.

Both academic and non-academic entities within the university are increasing connections to external stakeholders. This offers faculty and university units the opportunity to leverage new relationships. Events that take place at university or community co-working spaces increase the fluidity of knowledge exchange between university innovators and the community. For example, universities regularly draw on community resources to provide workshops on topics such as faculty startups, identifying funding sources, SBIR/STTR, grant writing, IP, the technology transfer process and legal issues. However, when the local community is not densely populated with entrepreneurial participants, there can be the risk of community fatigue as they attempt to support the many requests and demands to connect with the university.

Formal mentorship programs engage alumni or community partners in through entrepreneur-in-residence programs or other arrangements that help to fill the need for just-in-time education that is not tied to the academic calendar. Despite the fact that many alumni are located far away from the universities from which they graduated, university alumni centers leverage their networks to mentor faculty and student entrepreneurs. Alumni are invited to networking events, asked to judge competitions, review investment proposals and guest speak in classes. Some programs connect students or faculty with mentors in Silicon Valley or organize visits to the region for short-term workshops and/or tours of companies. However, despite technological advances in communication, barriers related to distance and levels of commitment are difficult to overcome.

On the regional, national and international levels, corporate relations activities have become more salient over time. Demonstrating an institution's business-friendliness has enabled individual faculty to establish unique commercial collaborations, with the added support of centers and units that help faculty identify new partners. Companies have even relocated to be closer to the talent pool (e.g. Menlo Innovations relocated their operation to Ann Arbor to be co-located with the U-M student incubator and co-funded the launch of a co-located community start-up space for early stage companies and a venture firm). It is clear that each of these initiatives influences the university and region as we move to a culture that increasingly rewards the long-term outcomes associated with entrepreneurship, as opposed to the short-term timelines traditionally afforded to scientific discovery and short-term commercialization outcomes.

Discussion

This paper presents an overview of the three large public universities involved in a national initiative designed to leverage their collective entrepreneurial resources for regional entrepreneurship and economic development. The selectivity associated with becoming an NSF I-Corps Node program signals that peer institutions consider these universities to have well-developed entrepreneurship programming and cultures with a high potential to contribute to their regions. The process of graphically diagramming the programmatic initiatives of each institution highlights the wide range of programs designed to support both student and faculty entrepreneurs, while fostering collaboration within and outside of

the university. Examining how these university initiatives align with the ecosystem literature shows that there are many similarities across institutions in terms of programming and resources and differences primarily have to do with administrative structures and stakeholders. Arriving at these diagrams was not a simple process. Discussing them with university stakeholders highlights the complexities and sensitivities having to do with administration, resources, ownership and who gets "credit" for entrepreneurial outcomes. Another limitation of presenting programming in this way is that the contributions of each initiative appear to be equal, and they do not reflect impact (e.g. activity, participants and return on investment). However, the diagrams are an important first step in understanding the interconnectedness of entrepreneurship activities at universities.

Technology transfer metrics are the primary way universities characterize their contributions to economic development; however, it is clear that they are insufficient to demonstrate the role that multiple university entities play in technology and talent development. This is particularly true in light of the numerous stakeholders and stakeholder interests. The use of these metrics is not surprising given that when universities first began formally supporting university technology commercialization activity, it followed a very linear model comprising discovery, disclosure, evaluation, patent application, market technology to firms, negotiate licensing, license technology, technology adoption in existing firms or creation of a startup (Bradley *et al.*, 2013). This model relied heavily on the technology transfer staff serving as business development experts for individual researchers, often resulting in criticisms of technology transfer office processes and their lack of adequate staffing (Swamidass and Vulasa, 2009). However, given the evolution of university entrepreneurship programming, and regional economic needs, a broader set of metrics could be envisioned.

To a large extent, the purpose of I-Corps is to bridge the gap between technology and talent development by educating faculty researchers to be their own business development experts. This is achieved by offering mentorship and network development through local, regional and even national ecosystems. The intent is to empower academic innovators with a better understanding of opportunity identification and the commercialization process that will allow them to take more active role in the technology transfer process, thereby reducing the burden of technology transfer on the staff. However, not all faculty want to be entrepreneurs, and it is important to keep the priorities of faculty and other stakeholders in mind while working toward this goal (Table V).

The inherent complexity of ecosystems and differing priorities in terms of stakeholder interests, units of analysis and access to data create challenges for university administrators looking to act on research findings for practical implementation in this area. Recognizing that published metrics were not a robust characterization of the complexities involved, Walshok and Shapiro (2014) proposed a framework for measuring an entrepreneurial university as a function of culture, commercialization supports, talent development and diversity of industry connections, in addition to technology transfer outputs universities (Walshok and Shapiro, 2014; Audretsch and Thurik, 2001). They also acknowledged the limitations of examining these factors, given that they are difficult to document by practitioners or researchers, and that making judgments related to stakeholder priorities is challenging. Even at the programmatic level within the field of academic entrepreneurship, little research is examining the effectiveness of entrepreneurship education strategies (i.e. Lean Launch, customer development and business model canvas) or the impact of entrepreneurship education on career choice or careers longitudinally.

Stakeholder	Objectives and Metrics
University leadership	Reputation and rankings
	Faculty recruiting
	Student recruiting
	Research funding
Technology transfer offices	Number of disclosures
	Number of patents
	Licensing agreements
	Dollars in licensing revenue
University-paid business development/incubator/accelerator staff	Number of startups formed
	Dollars of capital raised
External business development collaborators: e.g., entrepreneurs-in-residence; attorneys; investors	Number of startups formed
	New investment opportunities
	New job opportunities
	New clients, business, billable hours
Faculty	Obtaining research funding
	Supporting and training graduate students
	Advancing science
	Publishing research
	Tenure and promotion
Students	Completion of coursework and dissertation
	Obtaining and maintaining research assistantship
	Execution of research
	Meeting advisor expectations
	Obtaining jobs in their desired fields
Government-funded institutions and research centers (e.g. NSF/NIH)	ROI of investments in research
	# of commercialization grants awarded to researchers
	# of startups formed
	# of licensing agreements
	# of SBIR grants and follow-on funding obtained
	Educational outcomes
	Curricular change
	Institutional/cultural change
Communities	Reputation
	Economic development
	Job creation
	Quality of life

Table V. University entrepreneurial ecosystem stakeholders

Universities have the potential to contribute greatly to the vibrancy of regional entrepreneurship ecosystems, individually and collectively, given the significant resources they harness in terms of technology and talent development. However, the emergence of entrepreneurship programming is not always the result of university leaders reaching rational consensus; instead, it can be organic, political or opportunistic resulting from a grant opportunity or the particular interest of an administrator or a faculty member. At the macro level, more critical assessment university investments in entrepreneurial ecosystems could be of great value to both scholars and administrators, given expectations placed on universities to play a larger role in local economic development, while concurrently managing the cost of higher education. At the micro level, it would be useful to have answers to tactical questions such as how does university seed- and early-stage funding impact commercialization activity, the researcher, the university and/or regional economic

development? What is the most critical investment stage? Who is qualified to evaluate technology and make investment decisions? How is this being measured?

Regional entrepreneurial ecosystem models are still in development and are not directly transferrable to university entrepreneurial ecosystems. Nonetheless, recent work in this area can be used to inform efforts to establish university-wide metrics. In particular, Strangler and Bell-Masterson (2015) recognized that goals must be specific to communities, and most communities only look at input metrics. Most importantly, they identified the need to prioritize metrics, given that it is unreasonable to measure and assess all aspects of entrepreneurial ecosystems. Thus, for universities to establish relevant measures for goal setting and prioritization, it is critical to understand the complexities of university-wide activities. As a first step, we propose that universities consider framing their entrepreneurial ecosystems along the lines of the dimensions shown in Table VI to help prioritize outcome metrics. These dimensions represent the four entities involved in university programming as described above (academic, research administration, technology transfer and community engagement) in the context of the two primary outcomes, technology and talent development. This model will help focus discussions and identify metrics that can be measured and followed for real-time assessment and refinement.

Practical implications

We propose that universities involved in technology commercialization and entrepreneurship activities:

- reframe their focus on the needs and desires of individual stakeholders (Table V);
- re-visit their outcome metrics for technology commercialization, taking into consideration the four dimensions involved in university ecosystems (Table VI); and
- explore the interrelationships between university ecosystem dimensions.

Table VI.
University entrepreneurial ecosystem dimensions

Stakeholder	Technology development	Talent development
Academic	Graduate-level, project-based courses focused on technology commercialization	Undergraduate certificates or minors
	Promotion and tenure policies and practices	Individual entrepreneurship courses within academic units
		Product design courses
Research administration	Internal early stage funding	I-Corps workshops
	Sponsored research dollars	SBIR workshops
	Policies and practices	Competitions
Technology transfer	Technology transfer staffing and expertise	Entrepreneur-in-residence
	Internal business incubators	Mentorship
	Business development staffing and expertise	Awards and recognition
	Seed funds for technology or market assessment	
	Policies and practices	
Community engagement	Research parks	Seminars and workshops
	Technology parks	Networking opportunities
	Co-working spaces	Silicon Valley connections
	Access to investors	

This realignment and expanded view of outcomes will allow institutions the opportunity to develop tangible metrics that can be used for iterative, informed design that can be responsive to regional needs. This is not simple, as it requires reconsidering the units of analysis in university entrepreneurial ecosystems and associated university-industry, university-government and university-community partnerships that enable technology commercialization and entrepreneurship. It also requires that researchers consider *the individual* as a unit of analysis (in addition to *the institution*), recognizing that ecosystems represent many forms of human capital stakeholders, including students, faculty, staff, alumni and local community each having different priorities and goals.

It should also be noted that these priorities and goals are constantly evolving. For example, traditionally, universities have primarily been responsible for developing student critical thinking skills and experience; however, economic demand has pushed future employment to the forefront. Faculty have been responsible for teaching and research but today are experiencing greater demand to translate their innovations to promote new knowledge, whether it is commercial or noncommercial. Communities have traditionally looked toward universities for knowledge spillover, talent development and talent retention, but are now more engaged as active partners. These new paradigms require that universities prioritize stakeholders and outcomes.

There are other units of analysis to consider when measuring the impact of universities on regional ecosystems as well. The first is *timing*, or when to measure entrepreneurial outcomes, as it is clear that simply founding a company has little impact on economic development if there is no sustained development or employment. The second is *portability*, or the ability of ecosystem investments to transfer with individuals to other regions (e.g. investments in education and training versus investment in a co-working space). Finally, it is important to examine connections between elements of the ecosystem. After all, the term ecosystem is taken from the biological term and specifically identifies the critical interconnectedness of a system. If little is done to explore the strength of the connections, and how they are facilitated or prioritized, then we are left with a limited understanding of the system.

Conclusion

The intent of this manuscript is to begin a conversation around the desired outcomes and impacts associated with I-Corps and university entrepreneurial ecosystems *to bring practice closer to research*. It is clear that all programming is not equal, and there is an opportunity to isolate and examine metrics within and across programs. Given I-Corps' focus on both technology and talent development, and its emphasis on inter-institutional cooperation, it offers the opportunity to look at dimensions of ecosystems in a more manageable and representative way and answer questions such as how can we better define the contributions of university-wide entrepreneurial ecosystems? What are the right measures to use? How should institutions prioritize their efforts? How do we calculate return on investment, and for whom? To extract value from university-wide entrepreneurial ecosystems, significant efforts need to be made to bring practice closer to research by isolating aspects of university ecosystems so they can be studied. Given that this is a fairly nascent and evolving area of study, public universities have a responsibility to critical review their strategy within a context of many stakeholders. University contributions to technology and talent development are critical resources at stake for communities and society. Faced with economic and workforce trends, interest in evidence-based approaches to inform practice are of great interest to policy makers and university administrators.

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Appendix 1

Table AI.
Drivers for university investments in entrepreneurial ecosystems

	Michigan	UIUC	Purdue
INSTITUTIONALLY DRIVEN University investments that primarily benefit technology commercialization activities of the university	Center for Entrepreneurship I-Corps TechArb Student Venture Accelerator Entrepreneurs Leadership Program Zell Lurie Institute for Entrepreneurial Studies Entrepreneurial MAP Startup Workshops Center For Venture Capital & Private Equity Center for Social Impact Student Liaison Positions ZELL Entrepreneurship and Law Business Law Association Entrepreneurship Clinic Fast Forward Medical Innovation Michigan Translational Research and Commercialization for Life Sciences Innovation Hub GI Innovation Fund Monroe-Brown Seed Funding Therapeutic Innovation Fund Elizabeth and Jim Sweetnam Sleep Research Fund Traumatic Brain Injury Fund Innovation Studio Innovate Brew Innovation Blue MCubed	Entrepreneurship Forum Social Innovation @ Illinois Academy for Entrepreneurial Leadership Intellectual Property Clinic Technology Entrepreneur Center Faculty Entrepreneurial Fellows Founders Illinois Entrepreneurs Research Park EnterpriseWorks Entrepreneurs in Residence I-Start NSF I-Corps Site Office of Technology Management Proof of Concept Program	Purdue Office of Technology Commercialization Purdue Foundry Business Incubation ICorps Training FoundryX Office of the EXEC VP for Research and Partnership Burton D. Morgan Center for Entrepreneurship Deliberate Innovation for Faculty Fellows (DIFFs) Entrepreneurship Leadership Academy Office of the Provost Course: Life of a Faculty Entrepreneur: Discovery, Development, and Translation Graduate Entrepreneurship Club Discovery Park
COMMUNITY-DRIVEN Events that involve university resources in community engagement activity	TechLab @ Mcity Desai Accelerator Women Who Launch Ross Open Road	EnterpriseWorks Entrepreneurs in Residence I-Start Shared Services Program	The Railyard WomenIN Innovate Her Competition Foundry Grounds

(*continued*)

	Michigan	UIUC	Purdue
	Michigan Business & Entrepreneurial Law Review Entrepreneurial MAP Executive Education: QuantumShift	A.W.A.R.E. SBIR Technical Assistance Program Share the Vision Tech Showcase	The Anvil student coworking space Entrepreneurship Bootcamp for Veterans with Disabilities
INIVIDUALLY DRIVEN University investments that benefit individuals, regardless of location	ENTR 407: Entrepreneurship I-Corps The Startup Competition Jump Start Grant Startup Treks REAL TALK: Gender Equality Workshops Executive Education: QuantumShift Michigan Business Challenge Dare to Dream Grant Program Wolverine Fund Social Venture Fund Zell Early Stage Fund Zell Founders Fund Zell Entrepreneurs Program Ross Open Road Social Impact Challenge Board Fellowship Program Innovation in Action Competition PUBHLTH 622: Entrepreneurship and Innovation in Public Health EXCEL Program LSA optimize Program	Cozad New Venture Competition Innovation Prize Student Startup Madness Chicago Entrepreneurship Workshop IllinIdeas SocialFUSE Innovation Living Learning Community Silicon Valley Entrepreneurship Workshop Innovation Certificate Innovation, Leadership, and Engineering Entrepreneurship Certificate Technology Commercialization Certificate Business Management Certificate Strategic Technology Management NSF I-Corps Site Illinois Ventures	Startup Accelerator (The Boiler) Schurz Innovation Challenge Burton Morgan Business Plan Competition Cross Campus Certificate in Entrepreneurship and Innovation MBA Entrepreneurship Concentration Entrepreneurial Graduate Track Technology Realization Program ICorps Training

Table AI.

Appendix 2

Table AII.
University funding for entrepreneurial activity

	Examples
Types of funds	*Idea Generation*: In the age of interdisciplinary, universities are finding ways of bringing faculty together to generate new ideas. For example, in 2012, U-M launched M-Cubed to cultivate faculty from three difference disciplines to work together and conceive of new ideas *Opportunity Identification*: University research is largely funded through government funds that invest in research ideas. The launch of the NSF I-Corps program aims to provide mentoring faculty researchers in opportunity identification, business models and customer discovery. NSF I-Corps grantees are awarded $50,000 to enroll in the NSF I-Corps training *Commercialization Assessment*: Recognizing that commercialization assessment is not necessarily a core competence of university faculty, they have the opportunity to apply for funds to support commercialization assessment through consultants Proof of Concept/Prototype Funds: Competitive funds allow scientists to pursue proof of concept or develop early stage prototypes. These are typically short terms grants on the order of $50-$150,000 per year and milestone-based *Seed Capital and Early Stage Funding*: Seed capital and early stage funding has become more common. In some cases, participants receive funding to further their ventures, while gaining experience in venture financing
Sources of Funds	*Donors:* Alumni support student entrepreneurs in numerous ways, from funding individual entrepreneurial competitions, providing awards and scholarships or sponsoring student led venture funds *Public Private Partnerships:* Public private partnerships are cooperative agreements that have brought universities closer to local industries to leverage their strengths *Government funds (I-CORPS, SBIR/STTR)*: University faculty continues to leverage government funds for early stage development and opportunity identification *State Collaboration/External Funds:* Public universities collaborate government and economic development agencies on issues strategic to the state *University Venture Funds:* Universities have created their own venture funds for later stage investments. Michigan has the Investment in New Technology Startups (MINTS) program and Purdue has the Trask Innovation Fund and the Foundry Investment Fund

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