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Entrepreneurial education for the entrepreneurial university: a stakeholder perspective

Peter T. Gianiodis[1] · **William R. Meek**[2]

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Abstract
Entrepreneurial universities have gained increasing prominence across the globe and are now engines for regional economic development. While a few, elite universities are successful at developing and exploiting entrepreneurial capital, most universities have achieved only modest results, even after changing organizational structures, incentive systems and strategic priorities. Given this dichotomy, it is time for universities to examine how entrepreneurial education can play a greater role in shaping the entrepreneurial university model to exploit its benefits. We argue that the two institutionalized metrics—number of new firms formed and the amount of licensing revenue—used to evaluate performance of entrepreneurial universities are not easily applicable to science and technology entrepreneurship education. We integrate logic from stakeholder theory to provide a framework for explaining the relationship between entrepreneurship education and the formal and informal processes of technology commercialization within the entrepreneurial university. In addition, we advance a set of questions and performance metrics to evaluate entrepreneurial education initiatives inside of the entrepreneurial university. Thus, our paper includes educational assessment metrics reflecting the needs of a wider variety of stakeholders, including administrators, students, and technology commercialization offices. We conclude with a discussion on the implications for this framework including future research directions.

Keywords Academic entrepreneurship · Entrepreneurship education · Entrepreneurial universities · Performance metrics

JEL Classification I25 · L26 · L32 · O31

✉ Peter T. Gianiodis
gianiodisp@duq.edu

William R. Meek
wmeek1@udayton.edu

[1] Palumbo Donahue School of Business, Duquesne University, Pittsburgh, PA 15282, USA

[2] Department of Management/Marketing, School of Business Administration, University of Dayton, Dayton, OH 45469, USA

1 Introduction

Many universities have adopted the emerging *entrepreneurial university model*, whereby universities focus on economic development in addition to their teaching and research missions. This model has fundamentally changed the structure, processes, and for a select few, culture and mission of the university (e.g. Shane 2004). In fact, the belief among many stakeholders is that by adopting a variant of the entrepreneurial model, universities can be the fulcrum for the modern economy, which integrates disparate innovation capabilities within the broader regional entrepreneurial ecosystem (cf. Miller et al. 2014).

Declining funds from traditional sources have compelled many universities to seek alternative revenue streams; these universities have placed a disproportional emphasis on generating profits through entrepreneurship activities such as exploiting university-invented technologies (Stuart and Ding 2006). Yet, this pivot towards including innovation and economic development as equal priorities alongside research and teaching has not been a seamless transition for many universities. The emphasis on rent generation has created tensions; a larger number of university stakeholders, often with competing goals and interests, are now marginalized as they fight for limited university resources (Bischoff et al. 2018). In addition, evidence suggests that many universities seeking to generate higher levels of entrepreneurial activity have realized mixed results (cf. Hayter et al. 2018; Perkmann et al. 2013). For example, some universities have invested in new facilities and programs, while leveraging existing infrastructure—centers, incubators, science and technology parks, accelerators, etc.—to drive entrepreneurial activity and increase revenues (Chapple et al. 2005; Grimaldi et al. 2011; Mian et al. 2012; Siegel et al. 2007).

In this critical review, we integrate logic from stakeholder theory to address the challenges of migrating to and leveraging the entrepreneurial university model. Specifically, we provide a framework for explaining the relationship between entrepreneurship education and the formal and informal processes of technology commercialization within the entrepreneurial university. This is important given the growing incidence of student-led entrepreneurship initiatives and the need to embrace greater variety in academic entrepreneurship (Hayter et al. 2017; Siegel and Wright 2015; Wright et al. 2017). Thus, our guiding framework offers potential pathways for universities to weave a greater number and more robust entrepreneurial education initiatives into their formal academic entrepreneurship programs. Our framework refocuses on entrepreneurial education to consider how process and metric-centric models shape university-based entrepreneurial activities (cf. Rothaermel et al. 2007). This hybrid approach takes into account formal *and* informal links between entrepreneurship pedagogy and entrepreneurial activities that we argue are necessary to improve commercial outcomes (cf. Guerrero and Urbano 2012). One important advantage of a hybrid framework is that it explicitly acknowledges the inherent differences across contexts (cf. Bae et al. 2014); the entrepreneurial university is not as myopic as treated in the literature, and thus needs a more flexible framework to achieve desired outcomes for its myriad of stakeholders (cf. Gibb and Hannon 2006). Thus, the primary contribution of this study is to advance a framework that provides potential performance metrics for universities to evaluate the effectiveness of their entrepreneurship education activities, which will be the foundation for a stakeholder theory of entrepreneurial education and technology commercialization.

2 Stakeholders, entrepreneurship education and the entrepreneurial university model

The shift in emphasis on rent-seeking behaviors and the demands of generating entrepreneurship-based revenues fundamentally change university-stakeholder relations, especially for those groups that receive little benefit from these activities. Research is only now acknowledging the challenges universities confront related to expanded entrepreneurial activities (e.g. Meek and Wood 2016). The primary challenge relates to the alarming intra and inter-university disparities. The returns from entrepreneurial education and activities such as technology transfer and commercialization are unevenly spread with much of the gains concentrated in high profile academic units, and select universities located in fertile local entrepreneurial ecosystems (i.e. Stanford University-*Silicon Valley*, Cambridge University-*Silicon Fen*, MIT & Harvard-*Route 128*, just to name a few). Not surprisingly, many universities struggle to identify and fully integrate their entrepreneurship "value chain". This is especially true of the universities that were late adopters of entrepreneurial activities, and where the need for entrepreneurial education and activities alignment is greatest. While disproportionate gains may not be surprising given elite universities' inherent resource and location advantages, they do call into question the long-term viability of the entrepreneurial model at universities facing resource constraints (cf. Markman et al. 2008; Wright et al. 2004).

Despite the importance of entrepreneurial activities, there is still much to be learned about the link between entrepreneurial education and technology commercialization activities. In fact, this research has generally examined entrepreneurship education and university entrepreneurial ecosystems in relative isolation; entrepreneurship education typically focuses on students, whereas technology commercialization describes the professor's experience (for exceptions see; Bischoff et al. 2018; Guerrero et al. 2016; Hayter et al. 2018; Siegel and Wright 2015). Following recent research, we argue that there is a symbiotic relationship between entrepreneurship education, technology development, and entrepreneurial activities on university campuses (Bischoff et al. 2018; Nelson and Monsen 2014; Phan 2014; Wright et al. 2017). If this is the case, then aligning entrepreneurial education to entrepreneurial activities should be a university's priority. It may be the critical piece to reverse the negative returns from technology commercialization activities (e.g. Siegel and Wright 2015). Achieving alignment starts with stakeholder engagement, with identifying all pertinent *internal* and *external* stakeholders as the first step. Engaging stakeholders is critical because of their competing interests and asymmetric influence. Hence the need for robust metrics that satisfy each stakeholder groups' objectives because appeasing stakeholders retroactively is likely to intensify, not mute, the tensions among groups (Bischoff et al. 2018; Matlay 2009).

Stakeholder interests diverge most acutely around ownership/control and time horizon, which can make paths to commercialization highly contentious (e.g. Siegel and Wright 2015). We argue that this context is ripe for the application of stakeholder theory as the theory seeks to explain and predict how particular stakeholders or broad stakeholder groups *can affect and/or be affected* by business activities in which they are involved (Freeman 2010; O'kane et al. 2015). Scholars have only recently applied stakeholder theory to the technology transfer domain (e.g. Bischoff et al. 2018; Fitzgerald and Cunningham 2016). This limited research emphasizes the importance of collaboration within the broader entrepreneurial ecosystem in which the university is embedded (cf. Bischoff et al. 2018; Kuratko 2005). Universities collaborate through various mechanisms, with the emphasis on engaging stakeholders early,

articulating the goals and likely outcomes, and continuously building commitment throughout the process. An important piece of this engagement relates to entrepreneurial education; research suggests that gaining commitment from internal stakeholders, and collaborating with external stakeholders enhances the efficacy of educational programs (O'kane et al. 2015). For example, Bischoff et al. (2018, p. 31)) identified ten *support categories* for external stakeholder involvement in entrepreneurial education ranging from design to supervision and feedback. Importantly, some stakeholders will opt to participate as students/faculty translate their ideas from entrepreneurial labs (i.e. in the program) to new ventures (i.e. upon graduation). Thus, the link between entrepreneurial education and stakeholder engagement is clear—entrepreneurial activities are enhanced when universities leverage their stakeholders and build lasting relations.

Yet, research has not fully accounted for internal university stakeholders and potential intra-organizational conflicts that make entrepreneurial education and commercialization integration more difficult. This paper acknowledges this gap by including an expanded set of internal university stakeholders, and addressing associated issues that may affect entrepreneurial education integration. For example, as many universities have transitioned to the entrepreneurial university model they have changed their rent doctrines, defined as the incentive systems, policies, structures, and strategies that impact a research scientists desire to engage in university controlled technology commercialization activities (Gianiodis and Brown 2012). The result of this change sublimates value creation through technology transfer for rent appropriation from the commercialization of university-owned technologies (Gianiodis et al. 2016). However, university rent doctrines have often changed more rapidly than those of faculty researchers. Thus, we argue that identity adaptations need to occur to align university and individual faculty rent doctrine (Meek and Wood 2016). This is especially true given that certain scientific fields (i.e. medical sciences, mechanical engineering, chemical sciences, etc.) have developed their own rent doctrines. These scientific fields and their academic units within the university are enthusiastic about the change, but face resistance from other academic units that hold to the long-held Mertonian norms of open science.

In the next section, we advance a framework that considers a scientist's rent orientation and the rent doctrine of her university and scientific field, which extends recent research related to how role models and reward systems influence entrepreneurial attitudes in a given entrepreneurial university (Guerrero and Urbano 2013). By examining these factors, we can also understand how faculty mentors influence students' attitudes towards entrepreneurship education and participation in entrepreneurship and technology commercialization (Turner and Gianiodis 2018). Research suggests that the way in which graduate students are socialized in their educational program by faculty has a big impact on their own preferences towards the acceptability and desirability of formal technology commercialization activities in their own careers (Bercovitz and Feldman 2008). Thus, examining how certain stakeholders gain or lose influence as part of the transition and establishment of an entrepreneurial university model adds nuances to existing research on academic entrepreneurship within universities.

3 Frameworks for linking organizational resources and processes to performance

Depending upon mission and values, organizations have adopted various frameworks to link resources, processes and activities to relevant outcome metrics for evaluating performance (Scott 2003). These frameworks generally consider both economic (e.g. rents)

and social (e.g. health) outcomes on an economic-social continuum that range from a pure profit-oriented *economic framework* to one that has a societal focus, *social framework*. Organizations choose the processes to acquire resources that align to their chosen performance framework. While the alignment of organizational resources and outcome measures can change over time, organizations generally retain core elements of the system to evaluate performance (Siggelkow 2002). For example, non-profit hospitals have used strategic alliances to create *for-profit units* to compete in a more dynamic industry environment; however, they retain a *social framework* to serve their core mission (Brown et al. 2015). Likewise, when family-owned firms go public via an IPO, they have to adapt to greater financial scrutiny, but continue to value metrics related to family ownership such as control and succession (Lietterstorf and Rau 2014). Below we compare operational frameworks based upon several attributes including: strategic intent, operational focus, key stakeholders, relevant performance measures, and governance challenges. Table 1 provides a summary of differences between the frameworks.

A university's most important organizational resource is its human capital—faculty and their students who conduct and disseminate research to their scholarly community. The potential of scientists' human capital is derived from training and experience—scientists' educational background in terms of content, mentorship, etc.—shape their ability to create, and importantly for universities, to monetize their inventions. Enhancing scientists' human capital through education is a dynamic capability that many universities possess. Historically, academic education and training has been *science-centric*—knowledge to enhance scholarly pursuits and advance the scientist's field of study (e.g. Shah and Pahnke 2014). The gap in this program of study is clear—*skills needed to commercialize inventions or advance entrepreneurial opportunities are often not part of the educational experience*. Not surprisingly, universities that have adopted the entrepreneurial university model have faced challenges bridging this "skills" gap, especially universities that were late adopters or not embedded in robust entrepreneurial ecosystems (e.g. Wright et al. 2012). As universities expand beyond their founding mission, which emphasized knowledge creation and its dissemination within an open science regime, addressing this skills gap is critical to embracing the entrepreneurial model. However, many still rely on old modes of performance management, which do not adequately link knowledge creating inputs to commercial *and* non-commercial outputs.

3.1 Problems with current entrepreneurial university performance metrics

Prior research has emphasized the importance of two performance metrics: *revenues* from licensing and other activities and *new ventures or startups*. While Audretsch and Keilbach's (2004) definition of entrepreneurial capital consists of looking at the latter, the past decades of research suggest that many universities have a preference and a propensity to focus on licensing revenues to a greater extent than new venture formation (e.g. Markman et al. 2005). These two metrics have become institutionalized; they represent the status quo, or *profit-orientation framework* (POF) model, for assessing the entrepreneurial university. This places most universities at a disadvantage because these metrics are aspirational, especially for resource-constrained universities. Only elite universities perform well on these two metrics; the lesson, the rich stay rich while the aspirational universities rarely see breakthroughs (Grimaldi et al. 2011).

At its core, the POF model undervalues the university's traditional societal mission. Revenue maximization may clash with a university's potential societal impact; rather than

Table 1 Summary comparison of organizational performance frameworks

	Profit orientation: high-low (left-to-right)				
	Economic view (Friedman 1962)	Balanced scorecard (Kaplan and Norton 1992)	Triple bottom-line (Ho and Taylor 2007)	Sustainable enterprise (Dean and McMullen 2007)	Social enterprise (Frumkin 2005)
Strategic intent	Profit maximizing, short-term orientation for shareholders	Profit maximizing, short versus long-term balanced orientation	Balance maximizing—between profits, people, and planet—orientation	Sustainability maximizing, long-term orientation for sustainable development	Social maximizing, via "double bottom line" for key stakeholders
Resource bundles	Scale-based for cost minimization—exploitative leaning	Resource breadth—focus on exploitation and exploration	Balanced portfolio—internal and external sources	Boot-strapping via *resource-lite* bundles—internal and external sources	Partner-based portfolio—mostly via external sources
Operational focus	Focused on factors of production	Current competencies and future capabilities	Distributive competencies across stakeholders	Emerging competencies that address "wicked problems"	Justice-based competencies
Catalyst for adoption	Financial performance via efficiency gains	Short-term financial performance incentives distorts future investment	Leverage stakeholder interests for sustainable competitive advantage	Market failures create opportunities for alert and knowledgeable entrepreneurs	Societal need unable to be solved by a private enterprise
Key stakeholders	Shareholders and managers	Shareholders, managers, employees	Stakeholders: capital, product and organizational	Stakeholders: aligned with natural environmental needs	Stakeholders: community with social need
Relevant performance metrics	Two key metrics: (1) Financial (2) Accounting	Four key metrics: (1) Financial (2) Customer (3) Business processes (4) Learning and growing	Three key metrics: (1) Profits (financial) (2) People (stakeholders) (3) Planet (natural environment)	Three key metrics: (1) Profits (externalities) (2) Natural environment (3) Bricolage	Two key metrics: (1) Break-even (2) Mission-based outcomes
Governance challenge	Managing resource flows and attracting/retaining human capital	Managing short-termism; controlling for opportunistic behavior	Managing and aligning stakeholder goals	Solving market failures—externalities, imperfect info, flawed pricing, etc.	Securing and managing resources to fulfill organizational mission

solving global *wicked problems* (Camillus 2008), universities view technology transfer primarily as the mechanism to find the next *Gatorade* (i.e. discovered in 1965 by University of Florida scientists to support the university's football players). This emphasis may spur commercial thinking, but yields a disproportionate number of low impactful discoveries (e.g. apps). More troubling, research has found that universities' singular focus leads to tacit approval of *bypassing* where scientists appropriate much of the gains from commercialization (e.g. Dalton 2008; Gianiodis et al. 2016; Markman et al. 2008; Valdivia 2013). The risk is that the reliance on the *POF* model perpetuates sub-optimal outcomes for all but the most elite global entrepreneurial universities. In sum, the two primary metrics are neither appropriate nor comprehensive enough to properly assess the progress of most entrepreneurial universities wishing to increase the level of entrepreneurial activity via entrepreneurship education programs.

Given the weakness of the POF model, a hybrid-oriented framework (HOF) reconciles competing demands and better evaluates the university's overall societal *impact* related to entrepreneurial education linked to technology transfer activities. The HOF acknowledges the central role entrepreneurial universities play in regional economic development, as well as a potentially greater role in advancing social causes. For example, recent research highlighted critical environmental and internal factors that affect entrepreneurial universities; in particular, how these factors affect entrepreneurial outcomes (Guerrero and Urbano 2012). These authors distinguish between formal factors—organizational and governance structures, support measures for entrepreneurship, and entrepreneurship education—with more informal factors (e.g. word-of-mouth). This allows researchers and university administrators to specify and measure outcomes more accurately.

In the following section, we take up the challenge of specifying one of these formal factors—entrepreneurship education—in examining the effectiveness of the entrepreneurial university. We develop a set of potential entrepreneurship education performance metrics that better reflects, and thus evaluates, the role entrepreneurial education programs play in spurring entrepreneurial activity and technology transfer. In doing so, we extend recent research that was among the first to suggest that each university is unique and attitudes towards entrepreneurship among faculty and students were key in understanding this uniqueness (Guerrero and Urbano 2013). Further, this research suggested that factors such as *entrepreneurial education, teaching methodologies, role models and reward system (P.55)* are the biggest influencers of stakeholder alignment. Below we add to this conversation by looking at these factors and adding a new framework and a broader set of metrics to explain the role of entrepreneurial education in developing entrepreneurship capital in a U.S. context.

4 Entrepreneurship education metrics for the entrepreneurial university

4.1 Metrics for formal entrepreneurship education options

Much of the recent research has extolled the rise, growth and effectiveness of entrepreneurship education at universities across the globe (Fayolle et al. 2006; Kuratko 2005; Morris 2015). In particular, teaching students how to think critically and be creative in their assessment and evaluation of ideas has been influential in increasing the quality of student entrepreneurial ideas (e.g. Bae et al. 2014; Walter and Block 2016). In general,

universities have balanced local market needs (i.e. educational outcomes related to regional development) with national and global aspirations of its student populations (e.g. Shah and Pahnke 2014). This balance is a plausible starting point for designing metrics to evaluate a university's entrepreneurial capital, its processes for transforming this capital, and thus, its performance. Further, the range of entrepreneurship classes in terms of variety, scope, and the reach, especially entrepreneurship education outside of the schools of business or engineering (such as entrepreneurship in the arts or humanities), seems to be an emerging trend and a relevant metric to examine (e.g. Princeton Review undergraduate and graduate entrepreneurship rankings survey question in the U.S.).

In Table 2, we outline a framework and questions that inform metrics related to formal entrepreneurship education options. Fundamental to this framework is data and research drawn from the Global University Entrepreneurial Spirit Students' Survey (GUESSS). GUESS is a data collection effort and tool assessing the globalization of entrepreneurial education. Research using GUESSS data represents an excellent starting point for assessing questions related to formal entrepreneurship education metrics. Questions presented in Tables 2, 3 and 4 utilize and integrate logic and findings from the GUESS. For example, Item 2.1 in Table 2 assesses the absolute number of entrepreneurship courses offered by a university; several researchers have used this metric in published studies using GUESSS data (cf. Bergman, et al. 2018; Minola et al. 2016). To enhance the utility of this metric, we ask; *according to the university's strategic plan, what is the expected increase in the absolute number of entrepreneurship courses taken by students at the university*. This enhanced question indirectly gauges the extent to which universities are progressing towards the entrepreneurial university model. This aspirational question can be applied to all course content domains outlined in the tables; it allows university stakeholders to clearly state their aspirations and to determine if intentions match up to the current realities inside the university (Wright et al. 2017).

4.2 Student and alumni participation in new ventures and experiential learning

The number of new ventures formed by exploiting university discoveries remains the benchmark for measuring entrepreneurial capital in universities (Markman et al. 2009). However, this measure rarely captures the growing number of formal and informal ventures started by students (Siegel and Wright 2015). In fact, entrepreneurial activity often have their origin in student-led startups, aided by formal classes and programs, and informal communities on campus. Universities could follow the work of Guerrero and her colleagues by capturing data on the number of students who develop their own start-ups. Further, universities can enhance this data by tracking how student teams perform at local, regional or national new venture contests (cf. Kuratko 2005). Business plan and new venture pitch competitions are one of the milestones for measuring an entrepreneurial university's progress (e.g. Princeton Review Graduate and undergraduate entrepreneurship rankings in the U.S.).

Several recent studies (e.g. Bergman et al. 2018; Guerrero et al. 2016; Guerrero et al. 2018) have found evidence that the type of entrepreneurship education influences student entrepreneurship outcomes. To that end, using the percentage of student startup metrics as an alternative to the institutionalized performance metrics of new venture formations (university spinoffs) and licensing revenue is an important extension of the literature. Capturing these metrics, routinely done by elite universities who manage a cadre of incubators, accelerators, and other space that student-led teams occupy, is

Table 2 Metrics for formal entrepreneurship education options available over time

Metric	Change over time	Additional questions about future plans	Prior research supporting metric
2.1 University entrepreneurship curricular programs—absolute number of entrepreneurship courses/university curricula taken	(1) General entrepreneurship; (2) Family firms; (3) Early-stage financing; (4) Technology entrepreneurship; (5) Social entrepreneurship; (6) Entrepreneurial marketing; (7) Innovation and ideation; (8) Business planning; and (9) Other	Is there a plan or strategy to increase the absolute number of entrepreneurship courses taken at the university in the future?	GUESSS survey question: Morris et al. (2017), Bergmann et al. (2016) and Minola et al. (2016)
2.2 Elective entrepreneurship courses—participation rate	What is the share of students who have attended at least one entrepreneurship course as elective?	Is there a plan or strategy to increase the number of students who have attended at least one entrepreneurship course as an elective?	Bergman et al. (2018)
2.3 Compulsory entrepreneurship courses—participation rate	What is the share of students who have attended at least one entrepreneurship course as a regular part of their studies?	Is there a plan or strategy to increase the number of students who have attended at least one entrepreneurship course as a regular part of their studies?	Bergman et al. (2018)
2.4 Entrepreneurship courses—outside of schools of business and engineering	Is the university actively developing entrepreneurship courses aimed more specifically at students outside the school of business and engineering (i.e. in non-STEM units like the arts and humanities)	Is there a plan or strategy to increase the number of entrepreneurship courses aimed more specifically at students outside the school of business and engineering	Princeton review entrepreneurship ranking survey question?

Table 3 Metrics for student and alumni participation in entrepreneurial ventures and related experiential learning

Metric	Change over time	Future plans	Prior research supporting metric
3.1 Active student founders Percentage and total number of university students who have founded or are in the process of founding a new venture	Where did the idea/opportunity for new venture originate (i.e. in formal class, experiential entrepreneurship, prior experience, etc.)? What is the rate of change in the percentage (or absolute number) of student-founders of new venture relationship for ventures?	What is the university's strategy (if any) to increase the percentage (or absolute number) number of currently enrolled students that are founders or a founding team member of a new venture?	Students start ventures more than faculty (Åstebro et al. 2012) Students engage longer than faculty in new ventures over time (Boh et al. 2016) Graduate students are catalysts for faculty-led ventures (Hayter 2016)
3.2 Current student employee/intern in venture Percentage and total number of active students working as employees/interns in venture	What is the rate of change in active students working as employees or interns in a new venture?	What is the university's strategy (if any) to increase the number of active students that are employees or interns in a new venture?	Early exposure to ENT ideas and networks encourages long-term thinking (Roberts and Eesley 2009, 2011)
3.3 Alumni founders Number of alumni founders and/or founding team member of a new venture	What is the rate of change in alumni founders and/or founding team member of a new venture?	What is the university's strategy (if any) to increase the number of alumni founders/founding team members of a new venture?	Alumni embedded in the entrepreneurial ecosystem and act as a resource provider (Bischoff et al. 2018)
3.4 Alumni employee/interns Number of alumni are employees/interns in venture	What is the rate of change in alumni working as employees/interns in new ventures?	What is the university's strategy (if any) to increase the number of alumni that are employees or interns in new ventures?	No prior research, a new metric
3.5 Student participation in maker spaces Percentage and total number of students who use maker spaces	What is the rate of change in how many students use maker spaces?	What are the university's plans to increase the participation in its maker spaces?	Experiential/hands-on learning is more effective than lecture based ENT education (Bailetti 2011)
3.6 Student participation in incubators Percentage and total number of students who use incubators	What is the rate of change in how many students use incubators?	What are the university' plans to increase the participation in its incubator space?	Students more likely than faculty to continue in a new firm while on campus and through lifespan of the firm (Boh et al. 2016)
3.7 Student participation in research parks Percentage and total number of students in research parks	What is the rate of change in how many students use research parks?	What are the university's plans to increase the participation in its research park(s)?	Students with significant scientific and technical ability can make contributions to start-ups (Hayter 2016)

Table 4 Metrics for TTO role in developing entrepreneurship education/skills

Metric	Change over time	Future plans	Prior research supporting metric
4.1 University TTO rent doctrine How much focus does the TTO office put on monetizing university inventions (can look at TTO mission statements)	What is the share of the total budget that the university spent for the support of entrepreneurship in the financial year	Is there a plan or strategy to have a chair of entrepreneurship at the university in the future?	Bergman et al. (2018)
4.2 Informal TTO workshops and bootcamps How many informal entrepreneurship workshops and bootcamps are offered to students and faculty by the TTO at the university?	Since its origin, what is the change in the informal entrepreneurship workshops and bootcamps offered to students and faculty by the university's TTO?	What is the university's strategy (if any) to increase the informal entrepreneurship workshops/bootcamps offered to students and faculty by the TTO?	Learning by doing and building networks may be more effective than lecture based entrepreneurship education (Hayter et al. 2017, p. 1239; Bailetti 2011; Shah and Pahnke 2014)
4.3 Formal mentorship/internship programs Does the TTO offer formal mentorship and internship opportunities to undergraduate and graduate students interested in entrepreneurial initiatives (in the TTO itself or in university affiliated spinoffs/licensing companies)?	Since its origin, what is the change in the formal mentorship and internship experiences offered by the TTO to students interested in new ventures?	What is the university's strategy (if any) to increase the formal mentorship and internship experiences offered by the TTO to undergraduate and graduate students interested in new ventures?	Academic entrepreneurs and student entrepreneurs need role models to increase likelihood of their involvement (Bercovitz and Feldman 2008)
4.4 Surrogate entrepreneur formal process Does the TTO have a formal process to attract and recruit surrogate entrepreneurs to consider their university's innovations as the basis for a new business?	What is the change over time in the TTO's process to attract and recruit surrogate entrepreneurs to consider their university's innovations as the basis for a new business?	To what extent does the university TTO have future plans to develop a formal process to recruit surrogate entrepreneurs to consider their university's innovations as the basis for a new business?	Spinoffs often dependent on presence of surrogate entrepreneurs who provide network connections (Bray and Lee 2000; Carayannis et al. 2016; Clarysse and Moray 2004; Franklin et al. 2001; Hayter et al. 2018; Lockett et al. 2003; Lundqvist 2014; Vanaelst et al. 2006; Vohora et al. 2004; Würmseher 2017)

Table 4 (continued)

Metric	Change over time	Future plans	Prior research supporting metric
4.5 Surrogate entrepreneur list size How big is the list of potential surrogate entrepreneurs that routinely evaluates the catalog of university TTO innovation offerings?	What is the change over time in the size of the list of potential surrogate entrepreneurs that routinely evaluates the catalog of TTO innovation offerings?	To what extent does the university TTO have future plans to increase the size of the list of potential surrogate entrepreneurs that routinely evaluates the catalog of TTO innovation offerings?	Spinoffs often dependent on presence of surrogate entrepreneurs who provide network connections (Clarysse and Moray 2004; Franklin et al. 2001; Hayter et al. 2018; Lockett et al. 2003; Lundqvist 2014; Vanaelst et al. 2006)
4.6 Autonomy of TTO How much autonomy has the TTO been given by university administration to choose the best business practices in commercializing university innovations?	What is the change over time in the autonomy given to the TTO by university administration to choose the best business practices in commercializing university innovations?	To what extent does the university TTO have future plans to increase the level of autonomy given to them by university administration to choose the best business practices in commercializing university innovations?	

critical for other aspiring universities seeking to publicize their entrepreneurial credentials (Wright et al. 2017). In fact, universities have adopted few other performance metrics to document the existence, depth, or breadth of other types of student experiences similar to experiential entrepreneurial education (cf. Sánchez 2013). Capturing these metrics enhance the university's relationship with a broader set of stakeholders.

Additionally, capturing metrics related to student participation in a new venture in any form—as an employee, intern, or as a founder—serves as a socialization point for future preferences towards entrepreneurial activities (Bercovitz and Feldman 2008). While monitoring and supporting enrolled students are essential for making entrepreneurship education work, equally important is gathering longitudinal data as students graduate and become alumni. A useful measure for aspiring universities is how enrollment in entrepreneurial courses/programs predicted later entrepreneurial action, capturing the long-term benefits of entrepreneurial education and experiences (cf. Turner and Gianiodis 2018). Most entrepreneurship educators acknowledge that many of their students, especially undergraduates, will never start their own venture. In lieu of this, educators are charged with imparting an entrepreneurial mindset that is the critical deliverable for the course (Kuratko 2005), as early exposure to entrepreneurial experiences results in a long term entrepreneurial outlook (Roberts and Eesley 2011). Thus, engaging alumni, an external stakeholder group more likely to engage with the university's entrepreneurship education program, enhances the university's relationship with its local entrepreneurial ecosystem (Bischoff et al. 2018).

Given this acknowledgement, these metrics show the potential impact entrepreneurial education has on universities' entrepreneurial capital, and provides a mechanism for providing experiences that align current and former students' shared experiences and interests. Lastly, these metrics provide a baseline to compare and evaluate the impact of entrepreneurial education over time, which is notable given that recent research has found start-up rates for new ventures have risen in concentrated areas, but have fallen overall in recent years. Table 3 outlines some potential questions, rooted in theory and empirical research (e.g. Hayter et al. 2018; Wright et al. 2017), to serve as the basis for metrics to address these areas.

In addition to formal entrepreneurship education, a growing body of research suggests that better learning outcomes occur during experiential learning processes, and that enduring positive attitudes towards entrepreneurship are engendered when there is early exposure to entrepreneurial ideas and processes (Roberts and Eesley 2009, 2011). A similar stream of research has examined the importance of student-led entrepreneurship as compared to faculty-led ventures because (1) students start more ventures than faculty members (Åstebro et al. 2012) and, (2) students are likely to stay involved longer, throughout the life cycle of the venture (Boh et al. 2016). Further, research suggests that graduate students, in particular, play crucial roles in convincing faculty to start new ventures and often lead this process (Hayter 2016). While the field is beginning to learn more about the individual determinants and support mechanisms that impact graduate student startups (cf. Guerrero et al. 2018), the field would benefit from collecting more data and building robust models delineating the factors that drive graduate versus undergraduate student engagement in new ventures. Thus, the focus needs to include not only direct venture participation, but also participation in activities that equate similarly to some aspect of entrepreneurship, such as incubators, research parks, and maker spaces. Table 3 captures some of these ideas and provides a means to assess a starting point and an aspirant point for universities to gauge their efforts.

4.3 Role of technology transfer offices in developing entrepreneurship education

To this point, our focus as solely been on traditional entrepreneurial education course/program content and delivery. Recently, university's technology transfer office (TTO), the face of a university's technology commercialization infrastructure, have shown an interest in "skilling-up" the scientists with whom it works (Baglieri et al. 2018; Hayter et al. 2018). Primarily charged with integrating each stakeholder group to drive performance, TTOs are subject to simultaneous praise and criticism, as placating the myriad of stakeholder involved is quite challenging. TTOs have autonomy, which lets them effectively marshal discoveries through the many bureaucratic hurdles, but this may cause them to be too detached from the scientist's lab to fully understand, and support scientists' ambitions (cf. Chapple et al. 2005; Siegel et al. 2007). How university's build their organization and governance structures directly affect performance and will have an impact on the effectiveness of entrepreneurial education; research shows that the structure of the TTO, the university's primary mechanism for technology transfer and commercialization, is critical (Rothaermel et al. 2007). For example, Markman et al. (2008, 2009) found that TTO autonomy was associated with better information flows, higher scientist and stakeholder commitment, and performance. Likewise, greater autonomy gives TTOs the flexibility to leverage existing infrastructure and stakeholders such as business incubators, science parks, and angel investor networks, just to name a few (e.g. Mian et al. 2012; Link et al. 2015). Once the TTO structure is institutionalized, universities are positioned to integrate regional ecosystem components to build entrepreneurship capital.

Recent studies have posited that TTOs may have a key role in delivering a robust entrepreneurship program to enhance the skills among both faculty and student groups (Baglieri et al. 2018; Hayter et al. 2018; Siegel and Wright 2015). Further, TTOs overtime have acquired human capital to support new venture creation, rather than just act as a protector of university intellectual property and appropriator of rents for university innovation. Table 4 provides a framework and list of questions for examining the expanded role of TTOs in participating in entrepreneurship education, which can then yield meaningful metrics.

We argue that analyzing TTOs' influence in developing skills and providing entrepreneurial experiences is an important extension of academic entrepreneurship research. In particular, examining the frequency, depth, and competence level of TTO's in administering informal workshops and bootcamps for both faculty and students is a relevant metric. Further, research has documented the increase in surrogate (external) entrepreneurs on campus (e.g. Baglieri et al. 2018), but this is not uniformly documented at all universities. Thus, examining the mechanisms in which TTO's attract and create interest for their innovations among surrogate entrepreneurs is also important, given that research suggests some surrogate entrepreneurs might think of the TTO as a catalog of early stage ideas that can provide entrepreneurial inspiration (Wood and McKinley 2010). With the involvement of more surrogate entrepreneurs universities build entrepreneurial capital, which will likely increase the rate of new venture creation, and with support from faculty inventor and/or students, long-term success. The spillover effects—growing the size of the entrepreneurial ecosystem in which the university anchor—can be considerable.

4.4 University reward systems and the entrepreneurial climate

There is a significant body of research that examines different rewards systems entrepreneurial universities use (cf. Link et al. 2015; Siegel and Wright 2015). Much of this research focuses on incentives, but equally important are possible disincentives and/or

occasions for disenfranchisement. For example, a recent essay by Shepherd (2019) highlights how entrepreneurship manifests three distinct entrepreneurial *losses* or *damages*: (1) dark side outcomes, negative psychological and emotional reactions related to entrepreneurial action, (2) downside outcomes, organizational negative effects related to loss of capital and/or time, and (3) destructive outcomes, negative impacts to society related to entrepreneurial action. For this context, how the entrepreneurial university model disenfranchises certain stakeholders and how entrepreneurship education can alleviate this disenfranchisement are important considerations. Getting to the root of any possible university-faculty-stakeholder rent doctrine (mis)alignment is critical in understanding and preventing the 3-level losses and damages. For example, recent research on student perceptions of the university entrepreneurial climate (cf. Bergman et al. 2018) are important to build on to get a sense of what each different stakeholder groups think about the current trajectory and direction of their entrepreneurial university. Table 5 highlights some of these issues and offers a framework for examining important considerations of university reward systems, taking a much broader view than existing compensation-based incentives.

5 Discussion

This critical essay seeks to refocus research attention on the important link between entrepreneurial education and the formal and informal entrepreneurial processes within the entrepreneurial university model. After critically reviewing recent theoretical and empirical research, it proposes a framework for explaining this relationship, including how universities build entrepreneurial capital to impact their regional economy. While knowledge creation and technology transfer are core to what universities do, we agree with Mian et al. (2012) that a successful entrepreneurial university's impact should go beyond its organizational boundaries. We argue that a stakeholder view, asking broader questions and implementing a more diverse set of metrics, helps universities balance organizational and supra-organizational needs. Further, in universities' haste to implement formal entrepreneurship activities centered around appropriating rents from university-invented technologies, they have sublimated other important technology transfer activities, such as entrepreneurial education, which better reflect their mission. Thus, gaining an understanding of how entrepreneurial education can, in turn, impact the overall competency and level of academic entrepreneurship initiatives within the university is both noble and notable (cf. Pietrykowski 2001).

While the assessment metrics developed in this critical essay are not exhaustive, we believe that the framework and questions developed represent a useful extension of previous empirical work (e.g. GUESS). This framework redirects the focus on *efficiency measures* that support the interests of a narrow set of stakeholders, to *effectiveness measures*, that take into consideration entrepreneurial educational goals of a broader set of stakeholders and have lasting effects. We argue that this framework is a three-pillared catalyst: *first*, it is a catalyst for inquiry on the relationship between entrepreneurial education and technology commercialization; *second*, it helps universities align their entrepreneurial initiatives with their organizational mission, and *third*, it assists policy makers in supporting entrepreneurial education systems, as well as evaluating the university role within a local entrepreneurial ecosystem. We elaborate on each of the three pillars below.

Table 5 University support mechanisms, rewards structures, and entrepreneurial climate

Existence/amount	Change over time	Future plans	Literature justification
5.1 University's entrepreneurial budget as share of total university budget	What is the share of the total budget that the university spent for the support of entrepreneurship in the financial year	Is there a plan or strategy to have a chair of entrepreneurship at the university in the future?	Bergman et al. (2018)
5.2 Chair of entrepreneurship at university	Is there a chair of entrepreneurship at the university? (binary 1 = yes)	Is there a plan or strategy to have a chair of entrepreneurship at the University in the future?	Bergman et al. (2018)
5.3 Number of entrepreneurship competitions	What is the absolute number of entrepreneurship, business plan and idea competitions at the university in this academic year?	Is there a plan or strategy to institute or increase the number of entrepreneurship, business plan and idea competitions at the university in this academic year?	Bergman et al. (2018)
5.4 Student perceptions of the entrepreneurial climate	Please indicate to what extent you agree with the following statements about your university (1 = not at all, 7 = completely) At my university, students are encouraged to engage in entrepreneurial activities The atmosphere at my university inspires me to develop ideas for new businesses There is a favorable climate for becoming an entrepreneur at my university"	Is there a plan or strategy to improve the student perceptions of the entrepreneurial climate in the university?	Bergman et al. (2018) developed their own measure based on prior research concerning entrepreneurial climate
5.5 University co-curricular/experiential activities—absolute number of different offerings	(1) Workshops/networking with experienced entrepreneurs; (2) Contact platforms with potential investors; (3) Business plan contests/workshops; (4) Mentoring and coaching programs for entrepreneurs; (5) A contact point for entrepreneurial issues	Is there a plan or strategy to institute or increase the number of co-curricular/experiential activities offered at the university?	GUESSS variables/studies: Morris et al. (2017)

Table 5 (continued)

Existence/amount	Change over time	Future plans	Literature justification
5.6 Current university level rent doctrine/ trajectory	To what extent has the university's rent doctrine changed in recent years to focus more on appropriation of technological ideas?	Is there a strategy for an even greater expansion of university rent doctrine towards appropriation of university technology in the university? Is the university withdrawing from a past aggressive rent doctrine or change?	
5.7 Individual research scientist rent doctrine Field rent doctrine of each department on campus that is a stakeholder of the entrepreneurial university	To what extent have the rent doctrines and work identities of individual research scientists adapted to the changed/changing university rent doctrine?	Is the university offering identity adaptation pathways and information sessions extolling the benefits of technology commercialization to university research scientists?	Meek and Wood (2016)
Rent doctrine of each department on campus that is a stakeholder of the entrepreneurial university	To what extent is each individual academic department/scientific field in the university in line with the rent doctrine of the university?	Is the rent doctrine of a given scientific field becoming more accepting of commercialization or sticking to Mertonian norms of open science?	Meek and Wood (2016)

5.1 Pillar I: research

A critical essay, rooted in theory and empirical evidence, is intended to provoke thought and inspire further *and* divergent inquiry. The framework and questions, derived through critical inquiry, can form the basis of an extensive research program. Akin to the GUESS efforts, this framework easily translates into survey items using Likert type scales (see Table 6 for illustration), which can then be pilot tested across a wide variety of universities. In fact, this is already in process; researchers have modified the scales/items to fit the unique elements of a given university—size, location, programs, etc., and the desired goals for adopting an entrepreneurial model. We expect that over time researchers will assess the validity and reliability of these items, and with further theoretical refinement (i.e. supported by theories at multiple levels—*system*, e.g. institutional theory, *organization*, e.g. stakeholder theory, and *individual/team*, e.g. expectancy theory), can complement existing assessment measures.

While the primary focus of this critical essay is to inform scholars on how to investigate the linkages between entrepreneurship education and technology commercialization (Eesley et al. 2016; Guerrero et al. 2016; Nelson and Monsen 2014; Siegel and Wright 2015; Wright et al. 2007), we suggest that findings garnered from these studies have additional applications. For example, a critical element of technology transfer and commercialization is intra and inter-organizational knowledge transfer; results from empirical inquiry can inform the literature on knowledge spillovers and agglomeration. Likewise, a metrics-focused empirical examination can inform individual and team-level research related to motivation and performance, especially in the context of knowledge-based work (cf. Hayter 2016). Lastly, university-based entrepreneurial activity provides an excellent context for evaluating the negative externalities (i.e. Shepherd's "Dark Sides") of entrepreneurship at the individual, organizational and societal levels of analysis.

5.2 Pillar II: university administration

Beyond research, the framework presented can inform university administration at all levels within its hierarchy. At the university level, the framework can augment knowledge concerning resource allocation and structural effectiveness. At the college/school level, it can inform hiring and incentivizing decisions that may lead to better organizational citizenship behavior from faculty. Practice has followed scholarship in not applying a systems view, which results in underspecifying the stakeholders involved and the pertinent relationships that determine success from failure (cf. Gianiodis and Brown 2012; Kuratko 2005). This framework provides tools to implement needed changes at the organizational level (e.g. TLO autonomy), unit level (e.g. college and department entrepreneurial programs), and for the individual scientist.

Universities' financial conditions dictate the continued reliance on economic frameworks and metrics; however, as other researchers have argued (e.g. Link et al. 2015), universities need to balance their role of rent seeker with the needs of less salient stakeholders. In this way our framework, with its broader set of performance metrics for entrepreneurial education, is complementary to performance-oriented frameworks; we are challenging university administrators to not only enhance performance, but also be more experiential and integrate commercialization efforts with teaching and service activities. Providing leadership in this area while carrying out innovative activities can help promote a more balanced

Table 6 Potential survey items for questions posed in Tables 2, 3, 4 and 5

Table 5: Potential Survey Items for Questions Posed in Tables 2-5
Formal Entrepreneurship Classes (all) 1. How many formal entrepreneurship (ENT) classes (of all types) are offered (absolute number)?: 2. How many formal entrepreneurship (ENT) classes (of all types) are offered on the topics of: 1. General Entrepreneurship _____ 2. Family Firms? _____ 3. Early-stage financing? _____ 4. Technology entrepreneurship?_____ 5. Social entrepreneurship?_____ 6. Entrepreneurial marketing?_____ 7. Innovation and ideation?_____ 8. Business planning?_____ 9. Other._____ 3. Is there a plan or strategy to increase the absolute number of entrepreneurship courses taken at the university in the future?
Formal Entrepreneurship Course Participation Rates 1. What is the share (percentage) of all students who have attended at least one entrepreneurship course as a regular part of their undergraduate studies?_____ 2. What is the share (percentage) of all students who have attended at least one entrepreneurship course as an elective course as part of their undergraduate studies?_____ 3. What is the share (percentage) of all students who have attended at least one entrepreneurship course as a regular part of their graduate studies?_____ 4. What is the share (percentage) of all students who have attended at least one entrepreneurship course as an elective course as part of their graduate studies?_____ 5. Is there a plan or strategy to increase the number of students who have attended at least one entrepreneurship course as an elective? 6. Is there a plan or strategy to increase the number of students who have attended at least one entrepreneurship course as a regular part of their studies?
Percentage of Students Participating in Maker spaces, Incubators, and Research Parks? 1. What Percentage of students participate in maker spaces? _____ 2. What Percentage of alumni participate in maker spaces? _____ 3. What percentage of students participate in incubators? _____ 4. What Percentage of alumni participate in incubators? _____ 5. What percentage of students participate in research parks? _____ 6. What Percentage of alumni participate in research parks? _____
General Entrepreneurship Education Courses/Sections Growth Over Time *To No Extent* *To a large Extent* 1. To what extent have the number of entrepreneurship Classes (all types) offered on campus increased over time? (in 1,3,5,10 years) (i.e. -Total courses, number of course sections) 1 2 3 4 5 6 7
General Entrepreneurship Student Enrollment Change Over Time *To No Extent* *To a large Extent* 1. To what extent has the number of students enrolled in All entrepreneurship courses increased over time? 1 2 3 4 5 6 7
General Entrepreneurship Course Offering Changes Over Time *To No Extent* *To a large Extent* 1. To what extent have all (General) entrepreneurship Course Offerings Changed over time? (i.e. what offered, governance of classes/programs) 1 2 3 4 5 6 7

Table 6 (continued)

University Plans for Increasing Entrepreneurship Education (all types) *To No Extent* *To a large Extent* 1. To what extent does the university have future plans To increase student participation and the number of Entrepreneurship Classes offered? 1 2 3 4 5 6 7
Entrepreneurship Course Offerings Outside of Schools of Business and Engineering Changes Over Time *To No Extent* *To a large Extent* 1. To what extent have entrepreneurship Course Offerings outside of the schools of business and engineering changed over time? (i.e. what offered, governance of classes/programs) 1 2 3 4 5 6 7
Growth of Student Participation in Maker Spaces *To No Extent* *To a large Extent* 1. To what extent has student participation in Maker Spaces grown? (in 1,3,5,10 years) 1 2 3 4 5 6 7
University Plans for Increasing Student Participation in Maker Spaces *To No Extent* *To a large Extent* 2. To what extent does the university have plans To increase student participation in Maker Spaces? 1 2 3 4 5 6 7
Growth in Student Participation in Incubators *To No Extent* *To a large Extent* 1. To what extent has student participation in Incubators grown? (in 1,3,5,10 years) 1 2 3 4 5 6 7
University Plans for Increasing Student Participation in Incubators *To No Extent* *To a large Extent* 1. To what extent does the university have plans To increase student participation in Incubators? 1 2 3 4 5 6 7
Growth in Student Participation in Research Parks *To No Extent* *To a large Extent* 1. To what extent has student participation in Research Park Activity Grown? (in 1,3,5,10 years) 1 2 3 4 5 6 7
University Plans for Increasing Student Participation in Research Parks *To No Extent* *To a large Extent* 1. To what extent does the university have plans To increase student participation in Research Parks? 1 2 3 4 5 6 7
Current Student Founders How many students have founded or are in the process of founding a new venture: 1. In the School of Business? _____ 2. In Science and Technology Units? _____ 3. In Non-Science and Technology (S&T) Units? _____
Growth in Student Founders Over Time *To No Extent* *To a large Extent* 1. To what extent have the number of student founders (From all Units) increased over time? (in 1,3,5,10 years) 1 2 3 4 5 6 7

Table 6 (continued)

University Plans for Increasing Number of Founders Over Time *To No Extent* *To a large Extent* 1. To what extent does the university have a strategy to increase the number of currently enrolled students that are founders or a founding team member of a new venture (From all Units) over time? (in 1,3,5,10 years) 1 2 3 4 5 6 7
Current Student Employee/Interns in Science and Technology Based Venture How many students have been employees or interns in a new venture: 1. In the School of Business? _____ 2. In Science and Technology Units? _____ 3. In Non-Science and Technology (S&T) Units? _____
Growth in Student Employee/Interns in New Ventures Over Time *To No Extent* *To a large Extent* 1. To what extent have the number of student employee/ Interns in science and technology based ventures increased over time? (in 1,3,5,10 years) 1 2 3 4 5 6 7
University Plans for Increasing Number of Student Employee/Interns in Science and Technology Based Ventures Over Time *To No Extent* *To a large Extent* 1. To what extent does the university have a strategy to increase the number of currently enrolled students that are employees or interns in new ventures over time? (in 1,3,5,10 years) 1 2 3 4 5 6 7
Alumni Founders of Science & Technology Based Ventures How many alumni are founding team members of a Science & Technology based new venture? _____
Growth in Alumni Founders of Science and Technology Based Ventures Over Time *To No Extent* *To a large Extent* 1. To what extent have the number of Alumni founders of new ventures increased over time? (in 1,3,5,10 years) 1 2 3 4 5 6 7
University Plans for Increasing Number of Alumni Founders of Science and Technology Based Ventures Over Time *To No Extent* *To a large Extent* 1. To what extent does the university have a strategy to increase the number of alumni that are founders in new ventures over time? (in 1,3,5,10 years) 1 2 3 4 5 6 7
Alumni Employees in Science and Technology Based Ventures How many alumni are employees in a science and technology entrepreneurship based new venture? _____
Growth in Alumni Employees in new Ventures *To No Extent* *To a large Extent* 1. To what extent have the number of Alumni employees of new ventures increased over time? (in 1,3,5,10 years) 1 2 3 4 5 6 7

Table 6 (continued)

University Plans for Increasing Number of Alumni Employees in new Ventures Over Time *To No Extent* *To a large Extent* 1. To what extent does the university have a strategy to increase the number of alumni that are employees in Science and Technology based new ventures over time? (in 1,3,5,10 years) 1 2 3 4 5 6 7
Informal Technology Transfer Office (TTO) Workshops and Bootcamps How many informal Science and Technology based entrepreneurship workshops and bootcamps are offered to students and faculty by the TTO at the university? _____
Growth in Informal TTO Workshops and Bootcamps Offered Over Time *To No Extent* *To a large Extent* 1. To what extent have the number of informal TTO workshops and bootcamps offered to students and faculty increased over time? (in 1,3,5,10 years) 1 2 3 4 5 6 7
University Plans for Increasing Informal TTO workshops/bootcamps for students and faculty *To No Extent* *To a large Extent* 1. To what extent does the university have a strategy to increase the number of informal Science and Technology entrepreneurship workshops/ bootcamps offered to students and faculty over time? 1 2 3 4 5 6 7
TTO Formal Mentorship/Internship Programs Does the TTO offer formal mentorship and internship opportunities to undergraduate and graduate students interested in entrepreneurial initiatives (in the TTO itself or in university affiliated spinoffs/licensing companies)? _____
Growth in TTO Formal Mentorship/Internship Programs Over Time *To No Extent* *To a large Extent* 1. To what extent have the number of informal TTO workshops and bootcamps offered to students and faculty increased over time? (in 1,3,5,10 years) 1 2 3 4 5 6 7
University Plans for increasing TTO Formal Mentorship/Internship Programs *To No Extent* *To a large Extent* 1. To what extent does the university have a strategy to increase the number of formal mentorship/internship programs offered to students and faculty over time? 1 2 3 4 5 6 7 *TTO Surrogate Entrepreneur Formal Process* Does the TTO have a formal process to attract and recruit surrogate entrepreneurs to consider their university's innovations as the basis for a new business? _____
Change in TTO Surrogate Entrepreneur Formal Process over Time *To No Extent* *To a large Extent* 1. To what extent has the process to attract and recruit surrogate entrepreneurs to consider their university's innovations as the basis for a new business changed over time? (in 1,3,5,10 years) 1 2 3 4 5 6 7

Table 6 (continued)

University Plans to Change TTO Surrogate Entrepreneur List Size over Time *To No Extent* *To a large Extent* 1. To what extent does the university have a strategy to attract a greater number of surrogate entrepreneurs to work with the TTO and consider their university's innovations as the basis for a new business? 1 2 3 4 5 6 7
Autonomy of TTO *To No Extent* *To a large Extent* 1. To what extent has the TTO been given high levels of autonomy by university administration to choose the best business practices in commercializing university innovations? 1 2 3 4 5 6 7
TTO Autonomy Changes Over Time *To No Extent* *To a large Extent* 1. To what extent has the university given the TTO The autonomy to choose the best business practices in commercializing university innovations? 1 2 3 4 5 6 7
University Plans to Change TTO Autonomy Over Time *To No Extent* *To a large Extent* 1. To what extent does the university have future Plans to increase the level of autonomy given to TTO by university administration to choose the best business practices in commercializing university innovations? 1 2 3 4 5 6 7
University's entrepreneurial budget as share of total university budget What is the Share of the total budget that the university spent for the support of entrepreneurship in the financial year?
Chair of Entrepreneurship at University Is there a Chair of Entrepreneurship at the University? (Binary 1= yes) Is there a plan or strategy to have a chair of entrepreneurship at the University in the future if not one currently?
Number of Entrepreneurship Competitions What is the Absolute number of entrepreneurship, business plan and idea competitions at the university in this academic year?_____
Student Perceptions of the entrepreneurial climate Please indicate to what extent you agree with the following statements about your university *To No Extent* *To a large Extent* 1 2 3 4 5 6 7 •At my university, students are encouraged to engage in entrepreneurial activities. •The atmosphere at my university inspires me to develop ideas for new businesses. •There is a favorable climate for becoming an entrepreneur at my university."
(1) workshops/networking with experienced entrepreneurs; (2) contact platforms with potential investors; (3) business plan contests/workshops; (4) mentoring and coaching programs for entrepreneurs; (5) a contact point for entrepreneurial issues

view of how the university and the local community benefit from the entrepreneurial university model.

Lastly, these new entrepreneurial education metrics may be more salient for aspiring universities, where revenue generation and technology-based spinout activity metrics are beyond existing capabilities. Without providing explicit an adoption timeframe, our

Table 6 (continued)

University co-curricular/experiential activities *What is the absolute number of different offerings in the university?*_____ *Examples include:* (1) workshops/networking with experienced entrepreneurs; (2) contact platforms with potential investors; (3) business plan contests/workshops; (4) mentoring and coaching programs for entrepreneurs; (5) a contact point for entrepreneurial issues
Current University Level Rent Doctrine To what extent has the university's rent doctrine changed in recent years to focus more on appropriation of technological ideas? *To No Extent* *To a large Extent* 1 2 3 4 5 6 7
Individual research scientist rent doctrine To what extent have the rent doctrines and work identities of individual research scientists adapted to the changed/changing university rent doctrine? *To No Extent* *To a large Extent* 1 2 3 4 5 6 7 *Rent Doctrine of each academic department/scientific field in the university* To what extent is each individual academic department/scientific field in the university in line with the rent doctrine of the university? *To No Extent* *To a large Extent* 1 2 3 4 5 6 7

framework does include several questions that assess the changes in different university factors over time. Some universities and regions have looked to emulate the processes and structures employed by elite universities in a relatively short time-frame with the hope of replicating their results. However, we argue that it is important to have a reasonable perspective on how long systemic change is likely to take, if ever (i.e. replicate successful university-led regional economies such as Silicon valley, California, the Research Triangle in North Carolina, etc.). While some regions may be able to compress time, most require protracted periods of large-scale formal investment, informal network development, and innovative partnerships with powerful regional stakeholders to achieve success. To that end, this framework incorporates some levels of flexibility because each region should not always try to adopt *all* of the success measures of other regions.

5.3 Pillar III: public policy

Many government officials have embraced the promise of entrepreneurship education and technology commercialization as a means to achieve local, regional and/or national economic development goals. Their actions to support these initiatives, however, are generally

done in isolation or in fits and starts; current policy lacks the fundamental understanding of how educational inputs can inform the rate of participation, and thus the effectiveness of technology transfer operations. Government officials are guided by a mandate driven by powerful stakeholders and constrained by fluctuating financial resources, which can undermine comprehensive policy-making. Understanding the depth and breadth of regional university systems efforts committed to expanding entrepreneurial education and support programs can give public officials greater ammunition in steering needed resources to these efforts. Likewise, rich outcome data can help officials better assess the progress regional institutions are making in improving regional economic development. Data collection and comparison among different universities and different regions can also provide a sense of the amount of time systemic change efforts will take, and accordingly, the amount of patience and continued investments that local and regional governments will need to invest to further their economic development and entrepreneurial ecosystem goals.

6 Conclusions

Figure 1 shows how the three pillars share some common ground but also have distinct contributions for the field moving forward. Future research can focus on an individual pillar, but more impactful research will integrate each pillar as part of the larger educational-technology commercialization system. In particular, future research on the effectiveness of entrepreneurial education efforts within universities may need to consider an even broader set of metrics that represent the needs of additional stakeholders in the entrepreneurial university. For instance, politicians, governments, and university trustees, as well as local communities, alumni foundations, and university donors need to be committed to partnering with and embedding entrepreneurial initiatives into the regional ecosystem with a long-term time frame in mind. The authors have already started down this pathway, complementing efforts by Siegel and his colleagues, who are at the forefront of multi-level, multi-stakeholder academic entrepreneurship research (cf. Balven et al. 2018; Siegel and Leih 2018) Ensuring this long-term perspective, stakeholders will provide sufficient time and resource for changes in university structure, incentives, and entrepreneurial education to take effect. Further, this long-term orientation can ensure that economic development becomes a defining characteristic of both the university and the region, rather than a short-term reactionary response to revenue problems or other societal and political pressures.

In universities' haste to leverage technology commercialization to appropriate rents, they have sublimated other important technology transfer activity stakeholders, such as entrepreneurial education, that better reflects their mission. By offering this framework and attendant performance metrics, we are building momentum for a stakeholder model of the entrepreneurial university that follows recent scholarly work (cf. Bischoff et al. 2018). This framework is useful for proactively managing and evaluating universities' entrepreneurship education efforts within the broader regional ecosystem. While recent studies have grounded our thinking, we include additional measures to address the needs of different stakeholders in geographic areas outside of the U.S., UK, and EU. The next step is to test the validity and reliability of these metrics across different university and regional contexts, which the authors have begun. We look forward to thorough constructive discussion from academics, administrators, and practitioners in the field.

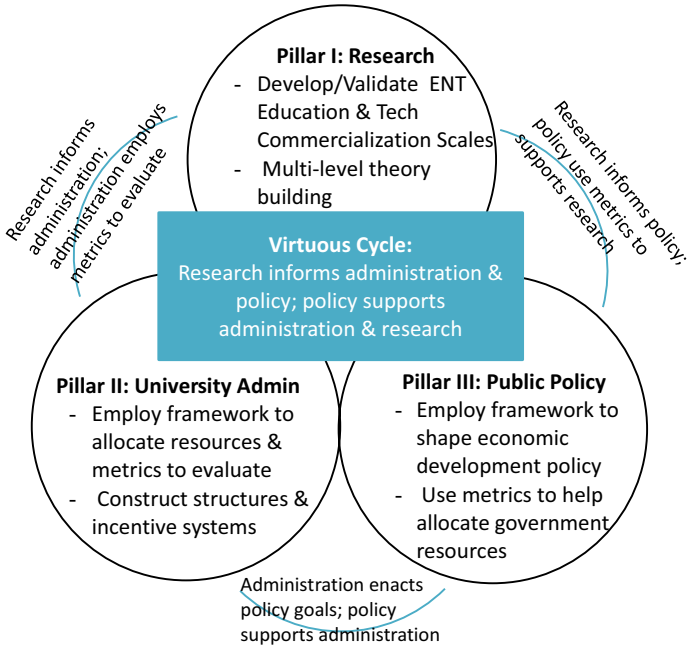

Fig. 1 Three-pronged pillars of entrepreneurship education and technology transfer

References

Åstebro, T., Bazzazian, N., & Braguinsky, S. (2012). Startups by recent university graduates and their faculty: Implications for university entrepreneurship policy. *Research Policy, 41*(4), 663–677.

Audretsch, D. B., & Keilbach, M. (2004). Entrepreneurship capital and economic performance. *Regional Studies, 38*(8), 949–959.

Bae, T., Qian, S., Miao, C., & Fiet, J. O. (2014). The relationship between entrepreneurial education and entrepreneurial intentions: A meta-analytic review. *Entrepreneurship Theory and Practice, 38*(2), 217–254.

Baglieri, D., Baldi, F., & Tucci, C. L. (2018). University technology transfer office business models: One size does not fit all. *Technovation, 76,* 51–63.

Bailetti, T. (2011). Fostering student entrepreneurship and university spinoff companies. *Technology Innovation Management Review*, *1*(1), 7–12.

Balven, R., Fenters, V., Siegel, D. S., & Waldman, D. (2018). Academic entrepreneurship: The roles of identity, motivation, championing education, work-life balance and organizational justice. *Academy of Management Perspectives, 32*(1), 21–42.

Bercovitz, J., & Feldman, M. (2008). Academic entrepreneurs: Organizational change at the individual level. *Organization Science, 19*(1), 69–89.

Bergman, H., Geissler, M., Hundt, C., & Grave, B. (2018). The climate for entrepreneurship at higher education institutions. *Research Policy, 47*(4), 700–716.

Bergmann, H., Hundt, C., & Sternberg, R. (2016). What makes student entrepreneurs? On the relevance (and irrelevance) of the university and the regional context for student start-ups. *Small Business Economics*, *47*(1), 53–76.

Bischoff, K., Volkmann, C. K., & Audretsch, D. B. (2018). Stakeholder collaboration in entrepreneurship education: An analysis of the entrepreneurial ecosystems of European higher education institutions. *Journal of Technology Transfer, 43,* 20–46.

Boh, W. F., De-Haan, U., & Strom, R. (2016). University technology transfer through entrepreneurship: Faculty and students in spinoffs. *The Journal of Technology Transfer, 41*(4), 661–669.
Bray, M. J., & Lee, J. N. (2000). University revenues from technology transfer: Licensing fees vs. equity positions. *Journal of Business Venturing*, *15*(5–6), 385–392.
Brown, J. A., Gianiodis, P. T., & Santoro, M. D. (2015). Following doctor's orders: Organizational change as a response to human capital bargaining power. *Organization Science, 26*(5), 1284–1300.
Camillus, J. C. (2008). Strategy as a wicked problem. *Harvard Business Review, 86,* 98–101.
Carayannis, E. G., Cherepovitsyn, A. Y., & Ilinova, A. A. (2016). Technology commercialization in entrepreneurial universities: The US and Russian experience. *The Journal of Technology Transfer*, *41*(5), 1135–1147.
Chapple, W., Lockett, A., Siegel, D. S., & Wright, M. (2005). Assessing the relative performance of UK university technology transfer offices: Parametric and non-parametric evidence. *Research Policy, 34*(4), 369–384.
Clarysse, B., & Moray, N. (2004). A process study of entrepreneurial team formation: The case of a research-based spin-off. *Journal of Business Venturing*, *19*(1), 55–79.
Dalton, R. (2008). Business: Stepping out. *Nature, 452*(7184), 146.
Dean, T. J., & McMullen, J. S. (2007). Toward a theory of sustainable enterprise: Reducing environmental degradation through entrepreneurial action. *Journal of Business Venturing, 22,* 50–76.
Eesley, C., Li, J., & Yang, D. (2016). Does institutional change in universities influence entrepreneurship? Evidence from China's Project 985. *Organization Science, 27,* 446–461.
Fayolle, A., Gailly, B., & Lassas-Clerc, N. (2006). Assessing the impact of entrepreneurship education programmes: A new methodology. *Journal of European industrial training, 30*(9), 701–720.
Fitzgerald, C., & Cunningham, J. A. (2016). Inside the university technology transfer office: Mission statement analysis. *The Journal of Technology Transfer, 41*(5), 1235–1246.
Franklin, S. J., Wright, M., & Lockett, A. (2001). Academic and surrogate entrepreneurs in university spinout companies. *The Journal of Technology Transfer*, *26*(1–2), 127–141.
Freeman, R. E. (2010). *Strategic management: A stakeholder approach*. Cambridge: Cambridge University Press.
Friedman, M. (1962). *Capitalism and freedom*. Chicago: University of Chicago Press.
Frumkin, P. (2005). *On being nonprofit: A conceptual primer*. Cambridge, MA: Harvard University Press.
Gianiodis, P. T., & Brown, J. A. (2012). University scientists' choice to commercialize their discoveries. *Advances in Entrepreneurship, Firm Emergence and Growth, 14,* 63–88.
Gianiodis, P. T., Markman, G. D., & Panagopoulos, A. (2016). Entrepreneurial universities and overt opportunism. *Small Business Economics, 47*(3), 609–631.
Gibb, A., & Hannon, P. (2006). Towards the entrepreneurial university. *International Journal of Entrepreneurship Education, 4*(1), 73–110.
Grimaldi, R., Kenney, M., Siegel, D. S., & Wright, M. (2011). 30 years after Bayh–Dole: Reassessing academic entrepreneurship. *Research Policy, 40*(8), 1045–1057.
Guerrero, M., & Urbano, D. (2012). The development of an entrepreneurial university. *Journal of Technology Transfer, 37,* 43–74.
Guerrero, M., & Urbano, D. (2013). Academics' start-up intentions and knowledge filters: An individual perspective of the knowledge spillover theory of entrepreneurship. *Small Business Economics, 43,* 57–74.
Guerrero, M., Urbano, D., Cunningham, J., & Gajón, E. (2018). Determinants of graduates' startups creation across a multicampus entrepreneurial university: The case of Monterrey Institute of Technology and Higher Education. *Journal of Small Business Management, 56,* 57–74.
Guerrero, M., Urbano, D., & Fayolle, A. (2016). Entrepreneurial activity and regional competitiveness: Evidence from European entrepreneurial universities. *Journal of Technology Transfer, 41,* 105–131.
Hayter, C. S. (2016). Constraining entrepreneurial development: A knowledge-based view of social networks among academic entrepreneurs. *Research Policy, 45*(2), 475–490.
Hayter, C. S., Lubynsky, R., & Maroulis, S. (2017). Who is the academic entrepreneur? The role of graduate students in the development of university spinoffs. *Journal of Technology Transfer, 42*(6), 1237–1254.
Hayter, C. S., Nelson, A. J., Zayed, S., & O'Connor, A. C. (2018). Conceptualizing academic entrepreneurship ecosystems: A review, analysis and extension of the literature. *Journal of Technology Transfer, 43*(4), 1039–1082.
Ho, L.-C., & Taylor, M. E. (2007). An empirical analysis of triple bottom-line reporting and its determinants: Evidence from the United States and Japan. *Journal of International Financial Management & Accounting, 18,* 123–150.

Kaplan, R. S., & Norton, D. P. (1992). The balanced scorecard—Measures that drive performance. *Harvard Business Review*, January–February, 71–79.
Kuratko, D. F. (2005). The emergence of entrepreneurship education: Development, trends, and challenges. *Entrepreneurship theory and practice, 29*(5), 577–598.
Lietterstorf, M. P., & Rau, S. B. (2014). Socioemotional wealth and IPO underpricing of family firms. *Strategic Management Journal, 35*(5), 751–760.
Link, A. N., Siegel, D. S., & Wright, M. (Eds.). (2015). *The Chicago handbook of university technology transfer and academic entrepreneurship*. Chicago: University of Chicago Press.
Lockett, A., Wright, M., & Franklin, S. J. (2003). Technology transfer and universities' spin-out strategies. *Small Business Economics*, *20*(2), 185–200.
Lundqvist, M. A. (2014). The importance of surrogate entrepreneurship for incubated Swedish technology ventures. *Technovation*, *34*(2), 93–100.
Markman, G. D., Gianiodis, P. G., & Phan, P. (2008). Full-time faculty or part-time entrepreneurs. *IEEE Transactions on Engineering Management, 55,* 29–36.
Markman, G. D., Gianiodis, P. T., & Phan, P. H. (2009). Supply-side innovation and technology commercialization. *Journal of Management Studies, 46*(4), 625–649.
Markman, G. D., Phan, P., Balkin, D., & Gianiodis, P. G. (2005). Entrepreneurship and university-based technology transfer. *Journal of Business Venturing, 20,* 241–263.
Matlay, H. (2009). Entrepreneurship education in the UK: A critical analysis of stakeholder involvement and expectations. *Journal of small business and enterprise development, 16*(2), 355–368.
Meek, W. R., & Wood, M. (2016). Navigating a sea of change: Identity misalignment and adaptation in academic entrepreneurship. *Entrepreneurship Theory and Practice, 40*(5), 1093–1120.
Mian, S., Fayolle, A., & Lamine, W. (2012). Building sustainable regional platforms for incubating science and technology businesses: Evidence from US and French science and technology parks. *The International Journal of Entrepreneurship and Innovation, 13,* 235–247.
Miller, K., McAdam, M., & McAdam, R. (2014). The changing university business model: A stakeholder perspective. *R&D Management, 44*(3), 265–287.
Minola, T., Donina, D., & Meoli, M. (2016). Students climbing the entrepreneurial ladder: Does university internationalization pay off? *Small Business Economics, 47*(3), 565–587.
Morris, M. H. (2015). Education, entrepreneurship and the unreasonable. In D. B. Audretsch, C. S. Hayter, & A. N. Link (Eds.), *Concise guide to entrepreneurship, technology and innovation*. UK: Edward Elgar Publishing.
Morris, M. H., Shirokova, G., & Tsukanova, T. (2017). Student entrepreneurship and the university ecosystem: A multi-country empirical exploration. *European Journal of International Management, 11*(1), 65–85.
Nelson, A. J., & Monsen, E. (2014). Teaching technology commercialization: Introduction to the special issue. *Journal of Technology Transfer, 39*(5), 774–779.
O'kane, C., Mangematin, V., Geoghegan, W., & Fitzgerald, C. (2015). University technology transfer offices: The search for identity to build legitimacy. *Research Policy, 44*(2), 421–437.
Perkmann, M., et al. (2013). Academic engagement and commercialization: A review of the literature on university-industry relations. *Research Policy, 42*(2), 423–442.
Phan, P. H. (2014). The business of translation: The Johns Hopkins University discovery to market program. *Journal of Technology Transfer, 39*(5), 809–817.
Pietrykowski, B. (2001). Information Technology and Commercialization of Knowledge: Corporate universities and class dynamics in an era of technological restructuring. *Journal of Economic Issues, 35*(2), 299–306.
Roberts, E. B., & Eesley, C. E. (2009). *Entrepreneurial impact: The role of MIT*. Kansas City, MO: Kauffman Foundation.
Roberts, E. B., & Eesley, C. E. (2011). Entrepreneurial impact: The role of MIT. *Foundations and Trends in Entrepreneurship, 7*(1–2), 1–149.
Rothaermel, F. T., Agung, S., & Jiang, L. (2007). University entrepreneurship: A taxonomy of the literature. *Industrial and Corporate Change, 16,* 691–791.
Sánchez, J. C. (2013). The impact of an entrepreneurship program on entrepreneurial competencies and intentions. *Journal of Small Business Management, 51*(3), 447–465.
Scott, W. R. (2003). *Organizations: Rational, natural, and open systems*. New York: Prentice-Hall.
Shah, S., & Pahnke, E. C. (2014). Parting the ivory curtain: Understanding how universities support a diverse set of startups. *Journal of Technology Transfer, 39*(5), 780–792.
Shane, S. (2004). *Academic entrepreneurship: University spinoffs and wealth creation*. Cheltenham: Edward Elgar Publishing.

Shepherd, D. (2019). Researching the dark side, downside, and destructive side of entrepreneurial action: It's the compassionate thing to do. *Academy of Management Discoveries*. https://doi.org/10.5465/amd.2018.0194.
Siegel, D. S., & Leih, S. (2018). Strategic management theory and universities: An overview of the special issue. *Strategic Organization, 16*(1), 6–11.
Siegel, D. S., Reinhilde, V., & Wright, M. (2007). Technology transfer offices and commercialization of university intellectual property: Performance and policy implications. *Oxford Review if Economic Policy, 23*(4), 640–660.
Siegel, D. S., & Wright, M. (2015). University technology transfer offices, licensing, start-ups. In *Chicago handbook of university technology transfer and academic entrepreneurship*. Chicago, IL: The University of Chicago Press.
Siggelkow, N. (2002). Evolution toward fit. *Administrative Science Quarterly, 47*(1), 125–159.
Stuart, T. E., & Ding, W. W. (2006). When do scientists become entrepreneurs? The social structural antecedents of commercial activity in the academic life sciences. *American Journal of Sociology, 112*(1), 97–144.
Turner, T., & Gianiodis, P. (2018). Entrepreneurship unleashed: Understanding entrepreneurial education outside of the business school. *Journal of Small Business Management, 56*(1), 131–149.
Valdivia, W. D. (2013). University start-ups: Critical for improving technology transfer. *Center for Technology Innovation at Brookings*, November, 1–22.
Vanaelst, I., Clarysse, B., Wright, M., Lockett, A., Moray, N., & S'Jegers, R. (2006). Entrepreneurial team development in academic spinouts: An examination of team heterogeneity. *Entrepreneurship Theory and Practice*, *30*(2), 249–271.
Vohora, A., Wright, M., & Lockett, A. (2004). Critical junctures in the development of university high-tech spinout companies. *Research Policy*, *33*(1), 147–175.
Walter, S. G., & Block, J. H. (2016). Outcomes of entrepreneurship education: An institutional perspective. *Journal of Business Venturing, 31*(2), 216–233.
Wood, M. S., & McKinley, W. (2010). The production of entrepreneurial opportunity: A constructivist perspective. *Strategic Entrepreneurship Journal, 4*(1), 66–84.
Wright, M., Birley, S., & Mosey, S. (2004). Entrepreneurship and university technology transfer. *The Journal of Technology Transfer, 29*(3), 235–246.
Wright, M., Hmieleski, K. M., Siegel, D. S., & Ensley, M. D. (2007). The role of human capital in technology entrepreneurship. *Entrepreneurship Theory and Practice*, *31*(6), 791–806.
Wright, M., Mosey, S., & Noke, H. (2012). Academic entrepreneurship and economic competitiveness: Rethinking the role of the entrepreneur. *Economics of Innovation and New Technology, 21,* 429–444.
Wright, M., Siegel, D. S., & Mustar, P. (2017). An emerging ecosystem for student start-ups. *The Journal of Technology Transfer, 42*(4), 909–922.
Würmseher, M. (2017). To each his own: Matching different entrepreneurial models to the academic scientist's individual needs. *Technovation*, *59*, 1–17.