

Entrepreneurial university dynamics: Structured ambivalence, relative deprivation and institution-formation in the Stanford innovation system

Etzkowitz Henry, Germain-Alamartine Eloïse, Keel Jisoo, Kumar Caleb, Smith Kaden Nelson, Albats Ekaterina

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Stanford's Innovation System: Structured Ambivalence and Intermediate Ties in Silicon Valley

Henry Etzkowitz

International Triple Helix Institute, Palo Alto

Eloise Germain-Alamartine¹

HELIX Competence Centre & PIE, Linköping University

Jisoo Keel

Stanford University, Science Technology and Society Program

Caleb Kumar

Stanford University, Science Technology and Society Program

Kaden Nelson Smith

Stanford University, Science Technology and Society Program

Ekaterina Albats

School of Business and Management, Lappeenranta University of Technology

Abstract

This article contributes to the debate over the entrepreneurial university. We utilize recent developments at Stanford as a laboratory to explore the entrepreneurial university transition, suggesting their relevance to academic institutions considering adopting this model. Exemplified by the relationship between Stanford University and Silicon Valley a vision emerged of the role of the university as a promoter of technological innovation. However, the development pathway of

¹ Corresponding author: eloise.germain@liu.se / Linköping University, Department of Management and Engineering, SE-581 83 Linköping, Sweden.

the entrepreneurial university is ill understood, even at Stanford, an iconic case. A gap opened up between Stanford and the Valley, due to an assumption of innovation as a laissez-faire phenomenon, despite close relations with firms that pre-dated Silicon Valley, and the more recent emergence of iconic firms, like CISCO and Google, from the university. In response, a series of translational and innovation support mechanisms have been founded, providing “intermediate ties” that link the academic and business worlds in a state of structured ambivalence.

Key Words: Entrepreneurial University, Stanford, Silicon Valley, Regional innovation, Intermediate Ties, Structured Ambivalence

1. Introduction: The Ambivalent Role of the Entrepreneurial University

The academic and policy debates over the entrepreneurial university are inextricably intertwined. Ever since the original conceptualization of the university taking a role in transforming knowledge into economic uses (Etzkowitz, 1983), the definition of university entrepreneurship has been at issue; more fundamentally there is the question of whether it should be accepted at all? (Bok, 2002). If undertaken, should it be encapsulated in a specific administrative function, a TTO or Science Park, or should it be integrated into research and teaching activities, as well? Articulating an appropriate degree of separation and integration places the entrepreneurial university in a perpetual tension of “structured ambivalence,” (Merton, 1976), a balancing act between academic and societal roles and various combinations thereof.

How should the university take into account the particularities of its surrounding region in defining an entrepreneurial mission? Whereas MIT pioneered the role of an entrepreneurial university in a declining industrial region; Stanford’s early practice illuminated its role in a developing region. In contrast to MIT’s original role in Boston, infusing new technology into an older industrial region—a “brownfield site”; Stanford’s early role was to assist the development of such an infrastructure in an agricultural region—“a Greenfield site” (Etzkowitz, 2002). Stanford helped create university- industry relationships and then university-government relationship. These double helices converged to form a Triple Helix that moved the region to its next stage of development in response to the crisis of regional recession during the 1990’s (Etzkowitz, 2013).

It’s very success in developing the world’s leading high-tech region has placed Stanford in a radically different context from its developing region origins. How should the university respond to this dramatic shift: declare success and revert to an Ivory Tower model in response to critics

who label Stanford “Get Rich U.” (Auletta, 2012)? Or double down on its entrepreneurial heritage, forge more extensive relationships to Silicon Valley, and take the model to new heights? These two positions have been an issue at Stanford, in recent years, behind the façade of an academic institution propelled to the front rank in global rankings.

How a hidden gap in entrepreneurial opportunity, a “paradox of success” was overcome is the topic of this article and its special contribution. This article proceeds as follows. Section 2 introduces the theoretical framework used in this case study by reviewing the literature. Section 3 presents the method, i.e. the research design and the implementation. Section 4 details the case of Stanford University and the problem of the innovation gap. Section 5 discusses initiatives that aim at bridging this gap. Section 6 suggests implications for policymakers and university managers. Finally, section 7 concludes the case study by summing up the research highlights, evoking limitations of the study and suggesting future lines of research.

2. Theory Development: The Entrepreneurial University in Theory and Practice

What is an entrepreneurial university and how to create one are matters of some debate, both within academia, the economic development policy arena and in the study of contemporary higher education. Some definitions focus on the relationship of the university to the larger society; others on its internal focus. An entrepreneurial university, defined in terms of culture, mission and regional role, assists the transition to a knowledge-based society as a key actor in the creation of new techno-economic conurbations (Balconi et al., 2010). Extension of traditional academic roles of teaching and research, as a side effect or direct goal arises most forcefully in reorientation of faculty to recognize useful as well as theoretical implications of research. Is creation of firms a valid academic output, informally through interaction of faculty and students with external providers of firm formation resources, skills, capital, and internally through incubation facilities and other support structures. How far should the university go in assisting the movement of potentially commercializable research into use, beyond the patent mechanism? Should inclusion of entrepreneurship courses in the curriculum in traditional and novel formats with simulation of practice, include actual events?

Ivory Tower and Entrepreneurial University

The Ivory Tower and Entrepreneurial University Models may be used to analyze “actually existing universities” as occupying a point on a continually shifting spectrum. Table 1 shows the “ideal typical” positions. Of course, most universities are in between.

Table 3. Contrast between Ivory Tower and Entrepreneurial University

No.	Spectrum Category	Ivory Tower University	Entrepreneurial University
1	University-society link	Isolated from the society	Open and serve to the external society
2	Teaching location	Teaching on campus	Teaching on/off campus
3	Knowledge mission	Knowledge production for own sake	Polyvalent knowledge produced
4	Research	Meandering stream of basic research	Multiple sources of input into research direction
5	Knowledge-related intention	Useful knowledge as accident	Useful knowledge sought
6	Technology and innovation transfer to industry	No organizational technology transfer capability and no firm formation	TTO, Incubator integrated into innovation strategy to foster start-ups
7	Disciplines organization	Discipline-based Departments as primary units	Departments and Inter-disciplinary Centres have equal status
8	Stakeholders	Single internal stakeholder	Multiple Stakeholders –internal and external
9	Source of university administration	University administration only from academia	University administration from multiple sources, including industry and government
10	Perception towards funding	Funding as matter of right	Funding as matter of exchange, something to be earned
11	Contribution point	Operation for self sustainability	Make significant contribution to regional development as well
12	Mind-set	Only academic mind-set	With entrepreneurial ethos

The entrepreneurial university may be defined in terms of the role of entrepreneurship in traditional research and teaching mission as well as its role in “third mission” for Innovation. Various universities have taking different paths to an entrepreneurial mode. Some traditional universities develop entrepreneurial training as an extension of their teaching missions. Other universities develop technology transfer as an extension of their research missions. Still others develop innovation support mechanism to facilitate firm formation and growth. Some universities

can choose to develop all these three aspects at the same time, or progressively, or just some of them. Five of these paths are described by Uyerra (2010), who names them differently. The entrepreneurial university can be found in this study as one model among the others. However, since Uyerra argues that these models are not exclusive, and since an economic role is only one of many possible relationships of the university to society we argue that all the models are in fact different configurations of the entrepreneurial university. For example, in the US, universities have traditionally encompassed various social welfare activities in a service mission which can be considered as societal and economic engagement.

In order to be successful, entrepreneurial education should be implemented in the framework of a favorable context (Pittaway & Cope, 2007; Klofsten & Jones-Evans, 2000) but, of course, it may be necessary to create such a context where it is not already in place. Indeed, that was the task confronting Stanford's founders in implanting an academic institution, with entrepreneurial ambitions, on a former ranch. Such a context can be composed of policies that fostered the creation of institutions for entrepreneurship teaching, such as the US Small Business Institute in 1972 (Solomon, 1975). The internal organization of the university is also a crucial element of the entrepreneurship education context. For example, a distribution requirement insuring that students with different interests and skills will meet provides an underlying substrate for entrepreneurial collaborations. Moreover, the governance and the attitude of both university management and academic staff towards commercialization of research can make the difference (Etzkowitz, 2003; Bienkowska et al., 2016). The configuration of relationships between the university and the private sector also counts, for instance, through the interactions between students and entrepreneurs (Brindley & Ritchie, 2000; Westhead et al., 2000).

In the recent literature on entrepreneurship education, few studies deal with its impact on business start-up or performance and socio-economic contributions, that are the expected outcomes of entrepreneurship teaching (Nabi et al., 2017). There is indeed a lack of empirical studies exploring potential links between entrepreneurship teaching and firm creation by trained students (ibid.). Teaching entrepreneurship seems to have a positive impact on the intention of students to launch a business (Peterman & Kennedy, 2003), but scientists struggle to collect longer-term observations. Nevertheless, the extensive and long-standing contributions of MIT and Stanford graduates have been noted, including the significant presence of MIT trained persons in Silicon Valley start-ups (Bank of Boston, 1997; Eesley and Miller, 2012).

There has been a significant shift in orientation of US business schools from a virtually universal preoccupation with preparing students for positions in existing business organizations to consideration of new venture formation. During the 1950's Prof. Georges Doriot's entrepreneurship preparation course in the Harvard Business School was disguised under the title of "Manufacturing" even as "entrepreneurship" emerged as an academic category at a research center elsewhere in the university. Since that era, entrepreneurial teaching formats have taken center stage. In the 1990s in particular, the number of courses, chairs and publications grew exponentially (Katz, 2003). Entrepreneurship education is a broad discipline (Fayolle et al., 2006), that comprises many sub disciplines such as entrepreneurial finance, or family business management (Katz, 2003). Entrepreneurship education is offered in many forms and pedagogical styles (Nabi et al., 2017) and at many levels of education, in postsecondary schools (Solomon et al., 1994) as well as at MBA and PhD levels (Bienkowska et al., 2016). It can be provided for instance through academic courses (Fayolle et al., 2006), but also through less traditional forms such as business plan competitions (Huffman & Quigley, 2002), mentoring or provision of network (Bischoff et al., 2017), or through entrepreneurial training aiming at starting a company (Klofsten & Lundmark, 2016).

As it is relatively new and since outcomes have not been precisely measured yet, entrepreneurship teaching is fraught with doubt and is the subject of scientific debate. Controversies persist over whether entrepreneurship can be taught or not (Kuratko, 2005), or the role of gender or family background in the likeliness to become an entrepreneur (Wang & Wong, 2004; De Martino & Barbato, 2003), or whether local culture has an influence on entrepreneurial activities (Fredin & Jogmark, 2017). In general, the literature has focused on entrepreneurship as an individual trait, whether in inherited or learned, relatively neglecting the collective nature of the entrepreneurial phenomenon (Schumpeter, 1951). An entrepreneurial hero tends to appear as an exemplar of success cases, eliding the contributions of others. While the technical contributions of Wozniak to Apples' origins is recognized, the key role of Mark Markkula, an experienced Silicon Valley executive who gave the nascent firm credibility with suppliers and vendors, is less noted (Freiberger and Swaine, 1999). This narrowing of visibility is less apparent in Scandinavia, where it is better recognized that entrepreneurship is not usually enacted until a group is ready to move.

Entrepreneurship education is an enabler of technology transfer (Drivas et al., 2016). With the addition of technology transfer to their traditional mission of research, entrepreneurial universities seek to answer the expectations of governments for them to have an impact on regional development (Nilsson, 2006), sometimes with “political pressure” (Siegel et al., 2007), through a “third mission” (Guldbrandsen & Slipersaeter, 2007), defined as “dissemination and outreach activities” (ibid., p.112). There is an intention to “make research relevant and accessible” (Gibb et al., 2013, p.7), both for the private sector but also for the public good, that can be realized from the commercialization of research.

In this sense, entrepreneurial universities might orientate their research towards applied sciences or create new academic fields (Audretsch, 2004) that can be later on valorized in some way. Technology transfer from the university to the non-academic world can be formalized in patenting and contracts with firms (Kalar & Antoncic, 2015). It can also happen informally, through collaboration, consulting and as a byproduct of teaching (Perkmann & Walsh, 2008). Channels for technology transfer vary in function, according to the scientific discipline, innovation time frame and industrial demand. Bekkers and Bodas Freitas (2008) give the example of the medical sector where students’ placements are part of the educational process as is also commonplace in engineering and other applied disciplines. Perkmann et al. (2013) gather both formal and informal forms of technology transfer under the concept of “academic engagement,” seen as a precursor to the commercialization of research. For Applied Science and so-called “Land Grant” universities and some disciplines, it can be part of their traditional research mission as in agricultural studies and chemical engineering (Mowery et al., 2015).

Commercialization of research is often the step following academic engagement but it may also proceed simultaneously and even be instituted as a result of an iconic commercialization event. Many universities encourage inventors to take this step (Perkmann et al., 2013) through the establishment of expert institutions in the matter, such as Technology Transfer Offices (TTOs). A TTO is an organization within the university dedicated to patenting and licensing, where researchers can get strategic and legal advice from experts (Macho-Stadler et al., 2007). TTOs are the “pivotal intermediaries in the entrepreneurial university” (O’Kane et al., 2015) and are increasingly present in developing as well as in advanced academic systems (Mori et al. eds, 2017). Their aim is to take into account both the expectations and constraints from the university as an institution, and the wishes and abilities of the researchers (Jensen et al., 2003). Colyvas (2007)

claims that entrepreneurial activities have found a legitimation in the university, but O’Kane et al. (2015) argue that TTOs have not, perhaps indicating the different stage of development of the entrepreneurial university phenomenon in the United States and Europe. A major part of university inventions is brought by researchers directly to the market, especially in Sweden, (Göktepe-Hultén, 2010), but also in the U.S where minor inventions may not rise to the level of a “disclosure.” A too narrow TTO specialization in one stage or phase of the innovation process, such as the legal forms of creating intellectual property, indicate the existence of a “bottleneck” in technology transfer (Swamidass & Vulasa, 2009, p.343). However, a narrow focus on numbers of commercialization projects, whether disclosures, patents or contracts processed by a TTO may ignore its broader role in university-industry relations (Bresnitz and Etzkowitz, 2015).

Debates persist on whether a valorization in the private sector could have a deleterious influence on the orientation or management of research or on the application of research results (Blumenthal et al., 1996; Toole and Czarnitziki, 2010). Conflicts of interest have to be managed, lest they explode into controversy as in the recent episode over the use of Facebook generated data in the Cambridge University Psychology Department research project in a spinoff. Review of spinoff projects by an experienced TTO in an academic system with clear guidelines on share of rewards and relationship between ongoing research activities and commercialization projects is an academic asset. Nevertheless, conflicts between inventors and TTO’s and between competing start-ups from the same university may spin out of control and enter formal conflict resolution systems in the form of law suits brought by universities and inventors, especially in the U.S. where a litigious mindset is widespread (Levitsky, 2018) .

In order to become entrepreneurial, the university has to provide a favorable context for entrepreneurship initiatives of its faculty, staff and students (Pittaway & Cope, 2007). D’Este et al. (2007) argue that university culture, policies and routines are key elements constituting such a context. Additional work on the internal organization of the university is necessary (Siegel et al., 2007). The HEInnovate working group, initiated by OECD and the European Commission, outline the key characteristics of an entrepreneurial higher education institution (Gibb et al., 2013). On top of that list is “Leadership and governance”, soon followed by “Organization capacity, people, incentives” (ibid., p.10). Leadership and governance can spread a common culture and vision

within the university in favor of entrepreneurship. However, this can fail if the rest of the university resists the orientation given by the leadership. Typically, there are a range of perspectives along a continuum from active engagement to strong resistance, located in different academic sectors with engineering and medicine most receptive and the humanities and social sciences most resistant (Liusite, 2018). Thus, the legitimation and the implementation of incentives promoting academic engagement and academic entrepreneurship seems necessary. This may take the form of positive incentives such as offers for funding for translational research and firm formation and negative incentives such as sharp reduction in university budgets.

Universities and regions have a major interest in encouraging the creation of companies (Gibb & Hannon, 2006) thus they develop university and regional policies to encourage it. Policies on Intellectual Property (IP) are an example. In Sweden for instance, university employees benefit from the “Professor’s Privilege” (Färnstrand Damsgaard & Thursby, 2012): inventors own the intellectual property of their invention, instead of the university as it is the case in many other countries (Rasmussen et al., 2006). Some believe that this encourages innovation since inventors get the whole profit of their invention and are free to dispose of it as they wish. On the other hand, less entrepreneurially inclined faculty may not pursue the commercial implications of their research or interact with the university’s TTO when the matter is left entirely in their hands. The U.S. Bayh Dole Act of 1980 represents an alternative approach that an increasing number of countries have followed, incentivizing universities to play a proactive role rather than leaving the matter to individual initiative.

The organization of a Technology Transfer Office (TTO) an internal administrative unit with legal, marketing and venture formation expertise, in varying degrees, is one example of innovation support mechanisms that a university develops to facilitate technology transfer to existing firms as well as new firm formation and growth. Science Parks and incubators are other examples (Audretsch, 2004). All are elements of innovation and entrepreneurial ecosystems that universities can help develop, where they can thrive and take part in economic development (Guerrero et al., 2016). An innovation and entrepreneurial ecosystem is defined as “a set of interconnected actors (potential and existing), entrepreneurial organizations (...), innovative organizations (...), and entrepreneurial and innovative processes (...) which formally and informally coalesce to connect, mediate by the government initiatives oriented to the performance of the local entrepreneurial environment” (Mason & Brown, 2014, p.5). Universities thus collaborate with a large number of stakeholders, and in a variety of ways (Bischoff et al., 2017). However, Isenberg (2011) highlights the central role of the university as provider of “specific

methodologies” for entrepreneurship training in such ecosystems (p.1). For instance, a key success factor of an entrepreneurial ecosystem is the presence of an “entrepreneurial champion” at the university (Rice et al., 2010, p.179).

These extensions of the traditional missions of the university are closely linked. Entrepreneurial training is a condition for technology transfer (Drivas et al., 2016), but both entrepreneurship teaching and technology transfer is inhibited without a favorable environment, or an entrepreneurial ecosystem (Pittaway et al., 2007). An entrepreneurial behavior at the individual level is taken for granted by some as a condition for innovation (Guerrero et al., 2016). The entrepreneurial university engages actors at all levels, both individually and collectively: university management, researchers-teachers, students, and organizations such as TTO (Bienkowska et al., 2016). But key persons and interests, within and without the university, are often the drivers for the establishment and maintenance of an entrepreneurial context (Rice et al., 2010).

Even the prototypical entrepreneurial universities, MIT and Stanford, pursued different, yet converging paths in their entrepreneurial development. Since there is not a unique path to becoming an entrepreneurial university (Gibb et al., 2013), case studies highlight different aspects of entrepreneurial university development. For instance, Guerrero and Urbano (2011) examine the formal and informal support mechanisms for entrepreneurship at the Autonomous University of Barcelona (UAB). They derive a model showing that UAB’s entrepreneurial identity comes from entrepreneurial features in education, research and innovation: in particular educational programs, entrepreneurial attitudes, incubators and governance structure. Bronstein and Reihlen (2014) sought to systematize the academic entrepreneurial transition, examining similarities and discrepancies among entrepreneurial university aspirants. They conducted a cluster analysis on 27 individual case studies across the world (except Africa), between 1998 and 2013 that resulted in a detailed typology of entrepreneurial universities’ archetypes. These mainly differ depending upon whether their main driver is research, industry, innovation or commerce (see Table 1).

Table 1 about here

Even though these archetypes do not entirely correspond to empirical reality, this classification seems to be consistent with additional case studies. Firstly, a more recent publication on the Twente University case (Lazzeretti & Tavoletti, 2005) mention the strong (self-)image of the university as entrepreneurial, the importance of business incubators and the Science Park environment, as well as the intensive creation of spin-offs. This corroborates the classification of Twente University in the “commerce-preneurial” archetype. The case of Chalmers (Jacob et al., 2003) would correspond to the “inno-preneurial” archetype. Although IP and venture capital are noteworthy at Chalmers and could make it oriented towards industry, other elements seem to show a stronger orientation towards innovation instead, such as the presence of an innovation center, its flexible structure adaptable to regional industry solicitations and its emphasis on consultancy. Another Swedish entrepreneurial university case, Linköping University (Svensson et al., 2012), can be viewed as “techni-preneurial”.

Indeed, its essential characteristics lie in its significant role mainly for its region, with strong links – both formal and informal - with regional stakeholders, not only public but also private (Germain-Alamartine, 2018). Of course, Linköping University also supports innovation and research commercialization. Finally, the case of the National University of Singapore (Wong et al., 2007) illustrates the “research-preneurial” archetype: although on patenting and research commercialization, the strongest impact of this university seems to be in entrepreneurial education, that reaches far beyond the geographical limits of its country.

Policies can be implemented through either “top-down” or “bottom-up” approaches (Goldfarb & Henrekson, 2002, p.639). In Sweden, policies are top-down since research funding comes mostly from the government. In the US, policies are bottom-up, because competition for research funding is stronger, encouraging academics to interact a lot more with industry. Nevertheless, in the U.S. government plays a strong role at the national, regional and local levels, often through grant programs that provide the equivalent of “public venture capital” in the guise of a research grant application that includes a second review for commercial potential (Etzkowitz, Gulbrandsen and Levitt, 2000). Some national programs mandate set-asides for less research-intensive regions even as most funds, whether for basic research or R&D tend to be concentrated at a relatively few schools that have successfully combined leadership in all three academic missions,

suggesting the existence of an add-on effect of confluence among education, research and entrepreneurship.

Depending upon a university's location in an existing or emerging industrial region; there is a likely different emphasis on dual university-industry and university-government from assisting firms within an existing industrial regime to forming new firms at the cusp of a new technological paradigm that the university itself is involved in creating, typically with government support. Superseding previous models of the university as relatively isolated from the larger society, the entrepreneurial university plays a leading role, interacting with other institutional spheres, in shaping the future course and development of a knowledge-based society, especially in the region where it is located. Academic missions are themselves a function of societal transformation with an educational mission appearing as precursor of transcendence of the medieval period and midwife to the birth of the modern era; a research mission appearing as a concomitant of the industrial revolution (the first academic revolution) and an entrepreneurial mission as part of the transition from an industrial to a knowledge-based society (the second academic revolution).

Stanford is a prototypical entrepreneurial university, an innovative academic institution, that continually renews itself and its region. Stanford has undergone a progressive development as an entrepreneurial university, revising its teaching and research roles, even as it developed a specific innovation role in recent years. Beyond interacting with existing firms, the core of the entrepreneurial university is its commitment to encouraging firm formation from existing knowledge that the university aggregates as well as new knowledge that it creates and transmits through its research and teaching missions.

Moreover, the criteria for success is always subject to reinterpretation. Stanford's leading role internationally in the early 21st century as a producer of start-ups induced a "paradox of success," precluding administrative examination of whether its performance could be improved: Nevertheless, aspirant entrepreneurs, attempting to follow the serial entrepreneur role model encountered difficulties and, even when successful, often concluded that their success was due to "luck". Perception of an entrepreneurial support gap, emanating from a variety of faculty and student sources, inspired a series of bottom up initiatives during the past decade. They are being

spread internationally, renewing Stanford's earlier status as entrepreneurial university role model through the invention of the science park in the 1950's and the market model TTO in the 1970's.

A larger unrealized potential of US universities in contributing to economic development, going well beyond the Stanford case, may be extrapolated from the experience of the University of Utah. Operating from a much smaller funded research base than MIT and Stanford, Utah has one of the highest rates of firm-formation in American universities. Utah views start-ups emanating from the university as part of its main mission, along with educating students and performing research, rather than as an accidental byproduct of these activities as is still commonplace at most universities. Participation in commercialization of research is credited in tenure and promotion proceedings, along with teaching and research. In contrast to schools where commercialization is de-facto relegated to the post-tenure career stage, junior faculty are encouraged, rather than discouraged, to be entrepreneurial since it is part of the academic reward structure.

There has been a rearguard action to deflect the university from academic entrepreneurship and maintain a traditional ivory tower ideal. This has taken place by redefining "entrepreneurial" from economic to non-economic activities. Another tactic was to question the generalizability of the entrepreneurial university model. However, although originating in engineering and agriculture, the model has spread more broadly to the medical school, basic science departments and most recently to the social sciences and arts. Significant exceptions were found to the entrepreneurial model, like Johns Hopkins, that were presumed to be tied to the ivory tower ideal. However, within a few years of the academic analysis of Hopkins exceptionalism (Feldman & Desrochers, 2004); the university joined the trend to academic entrepreneurship and indeed soon held up its model of technology transfer as a model for other universities to follow.

The wisdom of the university is that the three concepts of engagement, academic capitalism and entrepreneurship are potentially compatible. A university may be "engaged" and interact with society as a civic university through its educational mission and be entrepreneurial, contributing new ventures to its region (Goddard et.al 2016). Moreover, the "corporate university" or academic capitalism model serves as warning for universities to take care to protect their interests in negotiations with large corporations (Slaughter and Leslie, 1997). Rather than making agreements for large projects with individual firms, becoming tied to a single firm in any

industry, use models for joint participation of various companies in a pre-competitive research center! Each concept is an expression of different stages of university development and attitudes towards their respective missions: the engaged university of the teaching university, focused on cultural and social reproduction; the corporate university of the research university of the first academic revolution, and the entrepreneurial university of the Second Academic Revolution.

3. Method

The analysis originated in research carried out in 2005 by the first author, including participant observation in the Office of Technology Licensing (OTL) at Stanford University, archival research on informal engineering school technology transfer experience prior to the founding of an administrative unit. This was followed up with interviews, from 2012 to the present, with the founders and participants in a series of innovative organizations established within and without the university to foster technology transfer and firm formation, going beyond the marketing model of technology transfer to address a series of gaps from the identification of innovative potential of research findings to the organizational process of venture creation. The research design followed the classic biological model of going one level up (to university administrators e.g. the Dean of Research and one level down, to faculty and student program participants, as well as to the originators and organizers of the programs themselves.

Several follow up studies were undertaken by members of the Science, Technology and Society (STS) 186 Seminar on Innovation and Entrepreneurship in Spring 2017, led by two teachers from Stanford and Moscow State University. Its findings are the core of this article, the realization of the seminar course description that projected publication of its research results. The seminar of 10 members, primarily STS undergraduates but also including visitors to Stanford: a Silicon Valley venture capitalist, a highly successful Brazilian software entrepreneur and the director of the technology transfer office at a leading Chinese university. The seminar divided into three groups, each focused on different projects, utilizing a commonly developed interview guide. The seminar also heard presentations and conducted group interviews with Stanford entrepreneurs, the director of the Science Park and international experts in academic entrepreneurship, in person and virtually.

Preliminary results were regularly presented to seminar meetings before being developed into the joint case study papers drawn upon below.

4. The Case of Stanford University

4.1. Overview of the case

A proto-entrepreneurial university from its 1891 founding, Stanford was intended to play a role in regional economic development in order to create a support structure for the academic enterprise, especially in engineering, where a relationship with industry was a requisite. Stanford's early entrepreneurial interventions were top down, initiated by the university's leadership, supporting firm formation and establishing an interactive relationship with firms that had spun out of the university. After developing a support structure in the form of a science park to sustain these relationships as well as a technology transfer office to market future intellectual property outcomes of faculty research, the university stepped back from direct involvement. Nevertheless, a wave of "Ivory Tower" universities sought to jump-start entrepreneurial initiatives on their campuses in response to national policies, inspired by Stanford and MIT success, drew the academic sphere into a closer relationship to industry in order to renew economic growth.

From the 1980's while other universities took the organizational development of the entrepreneurial university model forward; the ethos of entrepreneurship that had been implanted in the start-up university's DNA spread from engineering to new areas, like computer science and biotechnology, and even music, as opportunities became available (Nelson, 2006). These flowed out through a relatively small group of serial entrepreneurs, who learned from colleagues how to pursue entrepreneurial opportunities, often through accepting a position on a Scientific Advisory Board, that gave access to start-up development strategy, and as intellectual property marketed by the OTL. Stanford's lack of basic mechanisms transfer mechanism that had become commonplace, like an incubator facility, while surprising to visitors, was explained away by OTL, which retained virtually sole official responsibility for entrepreneurship, as unnecessary due to the widespread availability of entrepreneurial support such as venture capital, in Silicon Valley, that had evolved into an innovation eco-system with venture capital, angels, law firms and private incubators.

A highly successful entrepreneurial university may fail to realize its full potential as senior administrators focus on past achievements and recognition received for its leading role. As Stanford University became more successful at technology transfer a “hidden gap” opened up as the TTO presumed that regional resources were doing enough to pull inventions out of the university without a push in the form of incubator and mentoring support from the office. Such a hands-off policy fit the needs of the university’s corps of serial entrepreneurs but disadvantaged faculty who were interested in pursuing entrepreneurial projects but lacked experience in negotiating with fund raising, finding experienced and trustworthy partners and the other entrepreneurial skills. This attitude tended to neglect the potential contributes of neophyte entrepreneurs, leaving their intellectual capital “on the table” as it were.

The 2005 study of (OTL) identified an “excluded middle” of neophyte inventors (in between the serial entrepreneur and opponents of entrepreneurship) with potentially commercializable research that was not systematically being translated into use (Etzkowitz, 2013). OTL with 25 staff members was primarily focused on serial entrepreneurs, whom they had worked with on successive commercialization projects, and did not have sufficient resources to seek out inventors who did not come to them directly. Occasionally, such an inventor was incentivized to find their own way to OTL but this was the exception rather than the rule. For example, a biology professor who did not believe in commercialization of research but wanted to see his invention built found a PhD Student in the engineering school who was interested in founding a firm. He made that the condition of realizing the biology professor’s goal of building his device and together they went through the OTL marketing and licensing process.

Nevertheless, this idiosyncratic example illustrated the existence of a broader entrepreneurial support gap at Stanford even though a solution was found in this particular case. Such a support structure has been created during the past decade or so and it has transformed OTL’s role from the one organization among several technology transfer modes. At other universities, TTO’s expanded to meet the needs of the intermediate group. Indeed, typically lacking a corps of serial entrepreneurs, the intermediate group of uninitiated potential entrepreneurs were their only available clientele and they therefore had to expand their purview in order to meet their needs and remain relevant (Etzkowitz and Goktepe, 2010).

The underachieving yet highly successful technology transfer office was a victim of the “paradox of success,” the tendency to blind oneself to flaws in its business model that reduced its potential contribution. But who would take such an analysis seriously in the face of success? The deleterious consequences of the paradox of success were not addressed until some of the university’s entrepreneurially oriented students who were especially affected by it, conducted their own study of barriers to entrepreneurship at Stanford and laid out a course of action to create an entrepreneurship mentoring and support structure to meet the needs of neophyte entrepreneurs (Etzkowitz, 2013). Additional measures were since instituted and others are suggested to further enhance the Stanford Innovation system.

4.2. *Origins of Stanford’s Paradox of Success*

A supportive environment for faculty entrepreneurship has been a recruitment advantage for Stanford as entrepreneurially oriented faculty gravitated towards Stanford before culture changed at other universities (Powell et al., 2007). Indeed, well after other universities had extended their control over intellectual property rights from federally funded research, Stanford, “... placed the rights, when possible, in the hands of faculty, staff, and students. The policy was changed in the mid-1990s, however, to mandatory ownership by Stanford University” (Gilmor, 2004: 154). Nevertheless, de facto policy to this day implicitly favors licensing to faculty start-ups.

Divergent faculty perspectives on technology transfer and commercialization of research may be identified based on interest and experience. Serial entrepreneurs, those with the most interest and experience, have “been there; done that, again and again.” These are the faculty members who have successfully invented and licensed technologies, created and sold firms based on their discoveries, or more precisely the discoveries of the members of their research groups. They are equally committed to basic research advanced discovery, and education. Indeed, much of the basis for their entrepreneurial success derives from their role as mentor of student inventors in their research groups. In this context, they may contribute their own ideas as well as nurture the ideas of their students.

Some serial entrepreneurs have evolved into informal entrepreneurial collectivities, pooling intellectual property and other resources with colleagues rather than only relying solely on their own efforts. For these experienced faculty, a disclosure to the university's TTO is both a box to be ticked and a valued resource for brainstorming additional applications of a discovery and additional contacts. However, the TTO will likely be primarily relying on the serial entrepreneur for leads to support the commercialization of their research rather than the other way around.

Stanford's serial entrepreneurs explore the multiple aspects of knowledge simultaneously, investigating theoretical and practical aspects, publishing and patenting as they go along; taking leaves of absence to engage in firm formation and/or sending out graduates to perform these functions backed up by an informal mentoring relationship, a formal advisory role on the firm's board of directors or Scientific Advisory Board and, quite possibly, a personal investment from funds earned from previous successes. These serial entrepreneurs have long time contacts with venture capitalists, links to angel networks and legal and accounting advisors at the ready to assist with evaluation of firm formation possibilities, in addition to the input from the university's TTO.

4.3. *The Emergence of an Innovation Gap at Stanford*

OTL plays an informal role in firm formation, initially by assessing the potential of the new technology as part of its marketing activities of contacting firms to see if there is any interest in licensing the new technology (Nelson, 2005). This “marketing activity” also provides a basis for assessment of the startup potential of the technology. Long-term licensing associates have good contacts in the Silicon Valley venture capital and legal communities. When they see an invention with significant potential for firm formation; they put the inventor into contact with potential sources of assistance, even if that help has not been requested. At that point it is up to the inventor “to pick up the ball.” OTL does not directly engage in business development, a task that university technology transfer offices explicitly undertake in emerging high-tech regions. Contemporary Stanford tech transfer practice relies on an informal dynamic to pull technology out of the university, without the need to provide in-depth support (Page, 2009).

OTL was so busy with serial entrepreneurs, or those aspiring to that status, that it has had little if any time to bother with inventors uninterested in pursuing the intellectual property implications of their work. Inexperienced faculty, who were interested in pursuing the commercial implications of their research were left largely on their own. This model worked well for a relatively small group of experienced faculty entrepreneurs, who spread their skills informally to colleagues.

Stanford administrators with responsibility for technology transfer believed that its unique location and the opportunities it offers, made it unnecessary for the university to take more explicit steps, commonplace at other universities, such as provision of an incubator facility. This laissez-faire attitude is encouraged by a pervasive empirical reality of serial faculty entrepreneurship, supported by the university’s vast experience in technology transfer, through its Office of Technology Licensing (OTL). A contemporary hands-off approach is encouraged by a previous celebrated history of hands-on involvement by faculty members, like Terman, in facilitating technology start-ups (Lecuyer, 2007).

However, it is often the case that OTL's marketing identifies potential areas of use and even users but does not result in an actual license. Firms typically view university originated technology as too early stage. They want to see it in use and better yet, already generating revenues. Thus, they would rather pay many times more to buy a start-up that has gone through the development and innovation process rather than undertake this task themselves, even though a license could have been obtained for a fraction of the cost. For example, an interdisciplinary collaboration in technology transfer that we examined was spurred by the need for engineering expertise to build a device for automating a biotechnology discovery process, with academic and industrial applications.

Until quite recently OTL has insufficiently addressed the intermediate group of faculty who have made discoveries that they duly report, and may have a moderate to strong interest in playing a role in commercialization. Their work often sits on the shelf as unlicensed IP, too little developed to be of interest to a potential licensee. To address these untapped opportunities OTL has created a "farm team" program through which an entrepreneurial team is recruited to commercialize inventions that the office has failed to transfer through the licensing process. An OTL program, the so-called birdseed fund, offers modest funds to graduate students to work on translational research in between medicine and engineering has been established, requires a minimum effort of an application on the part of an inventor to activate the program. OTL recently began turning over unlicensed disclosures to SPARK, a medical school initiative to encourage faculty to explore practical and commercial opportunities from their research, through the provision of seed funding and establishment of an entrepreneurship educational program.

4.3.1. SPARK Translational Research Program

The SPARK Translational Research Program was founded in 2006 by Daria Mochly-Rosen, Chemical and Systems Biology Professor at Stanford University. As she experienced an entrepreneurial success that she felt was the outcome of a random combination of factors, she had

the idea to develop a more systematic approach to move research projects “from bench to bedside”, thus aiming at filling an innovation gap at Stanford by providing translational research support to professors, clinicians, postdoctoral scholars, and graduate students. The program is mostly funded by the university (Stanford’s Medical School) and the federal government (National Institute of Health). It provides, during two years, entrepreneurial training in the form of lectures, but also practice through pitching and marketing. It also provides funding, developmental resources, mentoring from industry experts and a large network. 62% of SPARK projects have been successful, thanks to for example a strong relationship with Stanford’s Office of Technology Licensing (OTL). SPARK’s success reached outside the Medical School, since the program receives solicitations from other research departments, and since it is being replicated abroad. However, SPARK does not fully fill the identified innovation gap, as at the end of the two-year program, there is no extension of support for successful SPARK’s projects (Etzkowitz et al. forthcoming).

4.3.2. Stanford Student Government’s StartX Accelerator

With the US government ideologically constrained from direct intervention, state government lacking resources and regional government virtually non-existent in Silicon Valley, Stanford University’s student government acted as “Innovation Organizer,” providing a support structure to fill a hidden gap in the university’s innovation system. The StartX model intersects the university industry divide as StartX itself incorporates modified elements of both academic and business practice in its organizational design. Technology firms in Silicon Valley have previously been analyzed as constituting a network of relatively autonomous professionals, with links occurring through informal interactions among various firm’s employees, ‘creating a community of practice’ that transcends the boundaries of individual firms (Saxenian, 1996). StartX blurs the boundary between university and industry by creating an experiential educational process that assists the metamorphosis of intended into actual firms, drawing business people into an educational process while exposing academic firm founders to business reality in a nurturing manner.

It is potentially misleading to focus upon StartX, as an entity in itself, as a cure-all to facilitate greatly expanded university innovation results generally. StartX's significant relatively quick effect was possible at Stanford because a number of other elements of a university innovation system were already in place, form a broad variety of entrepreneurial education initiatives, a well-funded and well organized academic research system and a network of entrepreneurs and venture capital firms surrounding the university. Absent these elements, a StartX could wither on the vine as an isolated entity. Together with these elements, a StartX project can greatly expand the utilization of these resources, making it possible for a broader range of less experienced entrepreneurial projects to achieve take-off.

5. Discussion: Including Entrepreneurship in the Teaching and Research

Missions

The entrepreneurial university builds upon and extends previous academic missions of teaching and research by including training in entrepreneurship in the curriculum and by expanding the remit of research to include exploration of the practical outcomes of discovery. The entrepreneurial remit influences how the traditional missions are carried out and positions the university to play an expanded role in innovation.

Figure 1 outlines the Stanford innovation ecosystem – a snapshot of the set of actors (internal and external to Stanford), which operate and interrelate with each other to support a transformation of ideas, technologies and innovations originated from Stanford into either new firms (spin-offs and start-ups) or to the existing businesses (licensing out). Such a transformation takes indeed a communal effort of many of the innovation system actors or, in other words, “it takes a village” (OTL, 2017). One of the starting points of an idea or technology transformation into innovation is an external funding from private or public funds (the boxes marked with grey on the Figure 1) as e.g. National Institutes of Health (NIH) in healthcare.

On the Stanford side, the Office of Sponsored Research (OSR) provides pre- and post-award administrative services to projects that are funded. The further journey of the Stanford innovation through the ‘Valley of death’ and ‘Darwinian Sea’ (Auerswald & Branscomb, 2003) is very case

and context specific – with certain formal and less formal entities involved. Internally (within Stanford), the idea-innovation transformation may get supported through multiple, cross-disciplinary entities (pink-color boxes on the Figure 1). Among those are, for instance, Bio-X (supporting high-risk projects in the field of biological systems also with seed funds), Biodesign (training health technology innovators), SPARK (described earlier) and Spectrum (Stanford Center for Clinical and Translational Research and Education). Furthermore, multiple educational programmes training entrepreneurship mindset and translational skills are offered across faculties and levels (blue-color boxes on the Figure 1). Among those are for instance, ME310 programme on solving industrial challenges (Carleton & Leifer, 2009), d.school courses, Stanford Ignite certificate program on idea development and commercialization, Technology Venture Formation course (MS&E 273), Stanford Technology Ventures Program (STVP) and I-Corps programme on commercialization and technology entrepreneurship originated from STVP.

The entities surrounding Stanford including the Silicon Valley actors fall as integral part of the regional innovation ecosystem. Those include centers for industrial relations and social innovation as e.g. TomKat center for sustainable energy or Center for Automotive Research at Stanford (CARS), which bring together researchers, students, industry, government and community to support innovation transfer to society. The Silicon Valley as an ecosystem on its own represents a unique environment for Stanford innovation translation to business: business incubation and acceleration programmes (as AngelPad, Stanford-originated StartX, Y-Combinator), design, engineering and management consulting companies, law firms and banks, investors and venture capitals (Figure 1). Furthermore, local companies and outposts of the internationally-based ones (*“small offices geographically separated from company headquarters designed to tap into new technologies, cutting-edge research, and skilled labor that could be useful to their parent company [as BMW’s Palo Alto Technology Office], Stenholm et al., 2018, p. 2505*) also represent both customers and contributors for the Stanford-originated innovations. The formal transfer of the intellectual property rights on Stanford-originated inventions towards either a new or existing business is handled by Stanford OTL with support of its Industrial Contracts Office (ICO).

Despite all these actors successfully constituting the eco-system and despite the historical ties between Stanford and Silicon Valley, paradoxically, a continuing trajectory of identification of gaps is the hallmark of an iconic entrepreneurial university. In the following we discuss several recent initiatives that have filled gaps in the Stanford Innovation System. Whereas the entrepreneurial university model heretofore focused on technology that was presumably ready for transfer, whether to existing firms or as the basis of a startup, a revised model focuses on the

preconditions for technology transfer. Enhancing the educational and research academic activities. Although the innovations in entrepreneurship occurred at Stanford; the focus on preconditions, make the entrepreneurial academic model, more relevant to other universities.

Figure 1 about here

5.1.1. *The d.school*

The D-School began as an informal initiative to spread the basic principles of design thinking and problem solving to a broader group of students at the undergraduate level. The initiative built upon on more than 30 years of experience, combining mechanical engineering and arts methodologies that had been structured in ME310, a year-long program at the graduate level, to take in industry problem and develop solutions, through an inter-disciplinary team approach, offering a variety of prototyping resources in a dedicated space, with firm advisors available.

D-School courses are typically short, team taught, and inter-disciplinary often bringing faculty members from across the university together with practitioners. The d.school founders goals is to foster creative confidence in students and have them learn from cross-boundary interactive team exercises to gain experience and tools to use in different settings. The d.school states that the following 10 ingredients are essential to their success as a creativity-fostering intuition:

1. Be radically student-centered
2. Embrace clashing perspectives
3. Show unfinished work
4. Focus on the how not the what
5. Seek out fresh minds
6. Allow people to opt in
7. Build in room for change
8. Remember learning is a designed activity
9. Finding a balance between chaos and control
10. Pay attention to team dynamics.

The d.school emphasizes the importance each student has on the development of the community and classroom experience. The students' opinions and perspectives are taken into account by the teaching team. Additionally, the d.school stresses the significance and value of interdisciplinary teams and clashing perspectives in the journey towards innovation. They state, "many d.school methods are sparked by weaving together relevant disciplinary traditions from many fields", showing that by mitigating the effects of preformed conceptions and biases, new ways of thinking can be achieved. Showing unfinished work highlights the d.school's interest in the learning journey rather than the outcome. There are things to be learned from experimenting, even if a student does not reach their goal. Failing fast but using the experience gained is an essential part of the creative process.

The d.school rejects strict guidelines, allowing room for adjustment and change according to the specific issues of each situation and group. Although they give their students freedom, the processes which d.school classes implement are highly calculated and intentional. The learning process is meant to be stressful with no specific goal or constraints, in a delicate balance between chaos and control. The "choices are not accidents: they are the result of experimentation based on observable student behavior and honoring the fundamentals of the creative process"².

Lastly, there is a great emphasis put on team dynamics. "Bringing students together from different parts of the university on teams meant that in addition to using design to tackle complex, open-ended problems in an unfamiliar context, they simultaneously had to learn how to collaborate across disciplines and perspectives". The possible frictions caused by the misalignment of beliefs and ideals make for the creation of new innovative arguments and ideas and are essential to the way d.school classes are designed. The d.school receives multiple inquiries a week from government, university, and corporate institutions across the nation and world for help in

² See 5

replicating what they do at Stanford. However, their answer is not that simple. “Every context and culture has its own quirks...there is no one-size fits all recipe; it’s really up to you”³.

The D-School educational model has attracted significant interest outside of Stanford. Indeed, external interest and a wish to transfer the model has been the basis of significant support for the original Stanford project, gaining it resources to formalize itself; renovating old engineering buildings to provide a home and resources to hire permanent faculty rather than being dependent upon faculty volunteers and adjuncts from industry. Delegations regularly visit from other academic institutions to discuss and consider bringing the model home. Typically, as with a South African University, lacking the presence of a leading design firm adjacent to the university to draw upon for part-time faculty, a more academic version of the Stanford model is expected to be instituted.

5.1.2. Radicand: Design, Build, Test

Radicand was intended as an extension of an iconic Stanford innovation educational program. ME310 operates in a dedicated space available 24/7 to its members over the academic year duration of the course. Originating as a collaboration between professors from the Art and Mechanical Engineering Departments, ME310 is open to graduate students from across the university. A Stanford fixture for several decades, ME310 solicits problems and funding from industry for its student groups to work on with a firm advisor available for consultation. The results are typically passed on to the sponsoring firm to use or not. Occasionally, as a byproduct, ME310 student projects spin-off start-ups although that is not an objective of the course.

One objective of the Radicand project was to provide a venue for ME3110 graduates to take their projects forward. Radicand was founded to address the gap between hardware and software.

³ “How to start a d.school” *d.school*, Web, Accessed 3 June 2017

Software is very easy and cheap to create. People can make apps from their dorm rooms or start Apple in your parent's garage. hardware is a complete different beast, requiring much more space, equipment, and money. Radicand's mission is to find the most radical products because that is what is going to change design thinking. Radicand sets themselves apart from other hardware developers because of their approach to prototyping and the entire hardware development process.

Radicand applies design thinking and rapid prototyping to engineering development. Originally founded to provide a support structure to take campus originated projects forward; Radicand has become a design consulting firm and co-working space. Its staff works with solo entrepreneurs, startup teams, and established companies, utilizing its prototyping process of design, build, test. For those interested in working with Radicand, membership includes access to their facility and network of collaborators.

Greg Kress, CEO of Radicand, graduated from Michigan university with a degree in Engineering Physics before going on to Stanford for six years, where he earned his Master's in Mechanical Engineering and then a Ph.D in Mechanical Engineering. While studying for his Ph.D, he became a consultant for many large companies that focus on prototypes and product development. Also, Greg was a course assistant for the ME310 program where he worked with the student group directly. Following that, he became a graduate research assistant in the ME310 program and eventually became executive director of the program. In that position he participated in development, teaching, planning, and coordination with partner universities around the world.

After leaving Stanford, Greg spent a year at Aalto University in Finland. There he witnessed the university's advanced design factory, a large shared workplace for engineering students that produced real companies and real products. This is where he discovered the idea for Radicand. These students and advisors in Finland were collaborating well together, but students still seemed to struggle. One main struggle is that hardware is a very expensive process. It takes machines, space, time, and most importantly, money. These students have unreal ideas that are ground breaking, getting close but running out of money because they have nothing to show investors. "If a team has funding and is looking to develop a product, that's a very different set of objectives from those of a team that's not funded and needs to build a compelling demo to get investment," says Greg. This is the gap Greg found. Bringing not just these students, but all startups into his office space and him building the product with his staff. In one instance, two brothers who were into biking, were inspired to making a new helmet after a motorcycle crash. They wanted the helmet to be safe, but like no one has ever seen before. They wanted features such as 180-degree

rear-view camera, turn-by-turn GPS navigation, smartphone pairing and voice control. However, they were not capable of implementing these ideas, one of them graduated with a degree in psychology and had no idea how to build hardware.

That is why they were recommended to Radicand. Radicand is not the ones that go out and search for new startups, they go by only referrals or inbound request. When Radicand sees an opportunity in the marketplace, they take it and run with it. They first look at all previous products. For example, if they want to design a new pair of scissors, they will find every pair they have and lay them on a table. Then they see how they can drastically change the design and function and making a better end result. Greg calls this searching for the ‘dark horse’, a completely new way of thinking. Ask yourself questions like “Can your product be mind-controlled? Can you generate electricity from dirt? Can you custom design materials with anisotropic mechanical properties?” (Kress).

Radicand’s premise, as indicated by its name, is radical innovation. Its collaborators have to address the issue of funding. It is impossible to get funding by going to investors and telling them this great idea you have and not having anything to show them, so the key is prototyping quickly and cost efficiently. Before accepting the project, they ask many questions including: potential risks, possible experience failure, possible engineering failure, how does this product compare to others on the market, their ideas and previous attempts.

That is only the design thinking part, next it is about building a series of prototypes. It is important to know what you’re building; people do not build a home without a blueprint. Some engineers mix up prototyping and tinkering. Tinkering is when you’re building on the go and seeing what you can create. Prototyping is knowing what needs to be done and how you’re going to do it. Sometimes, it is not necessary to build prototype. For example, he wanted to create a temperature control for the kitchen so you can never burn food, he recreates the experience of a prototype but manually. He stood in the kitchen asked himself: did it work, what can be done differently, did it help? Greg emphasizes that there does not need to be a finished product for testing. It is important to test along the way and see what improvements could be made. In the end, that strategy is cheaper because it requires less prototypes and saves time. Greg also says “if you have a set of 50 features, you can start with one or two, demo the prototype, get feedback, and iterate.” If you were to make a finished product and then finally test it and it didn’t work, then you would have to start at ground zero. Slowly building up the product is much smarter and efficient.

Time is important because things are constantly developing. Rather than planning ten new projects then prototyping them, you have to take each project one at a time. When approached with an issue, it is important to act quickly. It is important to keep up to date on the newest technologies in the field, Greg says he can “3D print something in less than a day. We’re building, testing, and learning in these short little cycles as quickly as possible as we work toward that fully functional system prototype. So of course we have milestones and deadlines and all that but it’s really about just getting to work.” Also, Greg and Radicand have a strong belief that a small team is more efficient and better in this field. He knows he has the best engineers in the Valley and it is easy to create chemistry. A large team is difficult because they would struggle with agreeing on an approach.

Radicand also offers desk space for rent to startup companies. Radicand has headed in a different approach recently though. they had experimented with a couple different business models and ultimately decided to close their Redwood City co-working/ incubator in April of 2017 to focus on other things. They still offer a range of monthly memberships which includes access to Radicand’s collaborators and expertise. However, they usually negotiate custom memberships to fit the needs of every company. In some cases, Radicand will give space and access for free to the companies they have invested in or certain partners. They have worked projects with companies between as little as \$2k and \$200k.

5.1.3. Biodesign

Recognition of Stanford’s translational research gap, especially in emerging interdisciplinary fields, has inspired creation of various initiatives, such as BioX to encourage cooperation between engineering and the sciences, the “X” suffix designating an interdisciplinary and experimental intent of the program. In an earlier era, new sub-disciplines and departments such as applied physics were put in place to fill the gap between physics and electrical engineering. Biodesign starts from the opposite end, teasing out heretofore unrecognized problems for solution by having an interdisciplinary team of researchers shadow medical professionals as they go about their tasks. Each year a new team tackles a different clinical field, with the objective of developing a prototype solution.

Utilizing the Stanford Design School approach, Biodesign's founders developed a structured and replicable methodology of creating medical innovation. Based on the experience of a cardiology professor in inventing and commercializing a new type of stent and a medical school student with an engineering background who had also received an MBA degree, Biodesign focuses on a different clinical area each year. The biodesign program prioritizes the first stage of "opportunity assessment or Needs finding, defined as a "creative" open minded process of identifying opportunities for clinical innovation by direct observation of the everyday delivery of health care from the perspectives of multiple stakeholders, including patients, families, physicians, nurses" and health care reimbursors.

They created interdisciplinary teams of students with engineering, technical, law and medical backgrounds, though a fellowship model for a yearlong program with three stages: identification of clinical needs the invention of a solution" and implementation of that solution. The Biodesign fellow is encouraged to find a unique viewpoint to offer a novel solution for the clinical problem. The first part of the program consists of a curriculum to teach medical innovation, followed by exercise of the needs finding methodology to conduct needs scoping, identifying criteria of various needs stakeholder and analysis to identify the most attractive need before beginning development of a prototype solution to the problem identified. The Biodesign program requires its fellows to draft over 200 needs during the needs finding process. These needs are characterized and prioritized based on numerous factors including current understanding of the pathophysiology of a disease, the existing, and emerging treatment options, the potential market for a new technology and the various stakeholder interests.

Table 2 about here

The various initiatives address particular innovation gaps in various parts of the university. Spark focuses on the translational research gap in the medical school but similar lacunae exist elsewhere. ME310 is a cross-university initiative, open to a limited number of graduate students

each year. An Education School spin-off extends the format to a broader range of students. The D-School, operating primarily through short courses and workshops, takes the model further. Nevertheless, a way has yet to be found to realize the intention of Stanford's former President John Hennessey to include a D-School experience in the curriculum of all Stanford students. Radicand takes the ME 310 model off campus while StartX provides a de-facto start-up practicum for undergraduate students who take leaves from their formal training as well as for PhD students and faculty members. OTL has become a member of a virtual Innovation System during the past decade, providing valuable intellectual property protection and marketing services to Stanford students and faculty. Nevertheless, despite a board range of courses in the Graduate School of Business on topics like the lean start-up methodology, social innovation and the management of technology courses and degree available in the School of Engineering through the STVP Program, gaps remain, especially in the arts and social sciences.

6. Policy Implications

Stanford retains a decentralized structure of a TTO under the aegis of the Dean of Research, with other initiatives decentralized among academic departments or located externally to the university. To create linkages and synergies among these various projects and to fill remaining gaps, it is proposed that the university initiate an interdisciplinary and inter-organizational Innovation unit, crosscutting traditional administrative and academic boundaries, hereinafter called "I School," a concept specifically intended for Stanford that may be adapted to other university entrepreneurial trajectories and goals. An increasingly typical pattern has been for a research university that developed a TTO in response to the Bay-Dole Act of 1980 to expand its remit from licensing to a panoply of innovation support measures. Alternatively, such a university may make the TTO one of several services offered by a new Innovation administration unit, typically headed by a Vice President. The New Innovation thus arises in parallel with the university's research and teaching support structures.

The elements of a full-fledged university innovation system have been put in place in Stanford in recent years. Programs have been established that range from seeking out and solving problems to be solved, utilizing design thinking techniques to providing a pathway for incipient start-up conversations to be translated into organizational structures, with assistance in financing, including from the university itself. Most recently links have appeared between some of these programs so that they fill gaps and extend each other's reach. However, most of these programs are exemplary instances that exist in on part of the university that remain to be replicated and spread across the academic spectrum. These transformations of the university are by no means clear cut in time, space or sequence. Nevertheless, they have spread throughout the academic world in a variety of instantiations that are increasingly mapped and measured.

There is also lack of a coordinating mechanism to encourage links among the various initiatives. While design thinking has been integrated into the university's educational programs through the D School; other aspects of innovation such as IPR and are located in administrative units that perform their functions, without being integrated into the educational mission. Nor is there a think tank to undertake collaborative research on these issues that are studied by individual academics located in various parts of the university. Although Stanford draws in researchers and practitioners globally; during their time at Stanford, they are typically located in isolated settings and often do not meet and interact, except by chance. An innovation hub could provide a framework for intra and inter university innovation activities.

The premise is that Stanford, the academic global leader in innovation and entrepreneurship, has significant underutilized potential in this emerging academic field in practice, policy, theory and education. Existing "steeples of excellence" may become strengthened and gaps filled through creation of a novel interdisciplinary and inter-organizational Innovation unit, crosscutting traditional administrative and academic boundaries, hereinafter called I School.

The following steps are suggested to initiate I School:

1. Transition OTL from an administrative into a joint administrative/academic unit, with continuing responsibilities for technology transfer and with new responsibilities for education. OTL personnel would have a dual profile as Technology Transfer Officers and Innovation academics, offering a varied repertoire of short courses basic and advanced, allowing all faculty, graduate students and interested undergraduates to gain basic knowledge allowing them to recognize potential use, commercialization and intellectual property protection opportunity potential in their research and other intellectual and practical activities. Rather than moving OTL away from the main campus to Stanford's new administration campus in Redwood City as is currently intended, OTL should return to the academic core.
2. Loosely link the various elements of the "Stanford Innovation System" e.g. Spark, Biodesign, StartX, OTL etc. into a common Peer Council with occasional meetings to exchange ideas, foster collaboration and identify gaps. For example, Spark presently reviews OTL disclosures for potential recruits to their program but there is apparently no regular procedure for informing potential disclosees that this assistance might be a possible follow on to their disclosure if it were not yet ready for licensing. Awareness of such assistance would likely encourage additional early disclosures and make the general framework for innovation and entrepreneurship more systematic. Providing more points of assistance will enhance the flow of useful innovation. This is clearly the lesson to be derived from the StartX accelerator experience. Prior to its organization by students with an unmet need for entrepreneurial assistance, the general assumption was that the internationally recognized success of OTL and a start-up rate of 7 per annum made additional assistance unnecessary. A rise in the start-up rate to 30+ per annum after the founding of StartX in 09 demonstrated that Stanford was impeded in improving its performance by a "paradox of success" as the international leader had difficulty in recognizing that there was room for further improvement.
3. We suggest that there is still significant room for improvement, simply by replicating the above-mentioned programs into underserved academic areas, including the humanities and social sciences, creatively adapting them as necessary to local circumstances. There is also room to introduce innovation formats commonplace elsewhere that are barely utilized at Stanford. In the incubator space, there is the modest exception of StartX's bio incubator, assisted by UCSF's QB3 project. Formal incubation barely exists at Stanford, encouraged

by the belief that Stanford as a whole in an incubator. While there is certainly truth in this adage, formal structures would especially be helpful in the biomedical area and other fields where a longer-term support structure is required than a 3-month accelerator program to bring ideas to fruition. These lacunae could be remedied in the short term by encouraging incubation of the early stages of start-ups in faculty labs, a process that occurs naturally and informally but could be extended into the formal start-up process by legitimizing dual roles in firm and lab for faculty, PhD students and post docs following the Brazilian innovation model. US inurement regulations or presumptions might have to be adjusted. Stanford could take the lead in this revision of academia, aligning research and entrepreneurship.

4. To accommodate additional space needs the Stanford Research Park, should gradually be transformed into an innovation campus, hosting joint research groups, firms and center collaborations that are beyond the scale of existing academic buildings. While the limited scale of the park is no longer suitable for high growth firms like Facebook, it is eminently suitable to operate as a super incubator. Leases should be renegotiated and shortened to make available space for this new function. The location of StartX in the park is a beginning that should be expanded a hundred-fold during the next two decades.
5. These various specific initiatives require a strategic planning, research and educational element to make them fully effective and create a momentum of new ideas and initiatives into the future. To this end, an I School should be founded within the arts and sciences as an interdisciplinary research, training, consulting and planning unit. Partial Models exist in the U.K. SPRU Science Policy Research Unit, Sussex University, the Electrum Foundation in Kista Science Park, Stockholm and elsewhere in Europe, Latin America and Asia. SPRU offers masters and PhD programs in science and technology policy and maintains an extensive research program in this field but has no comparable US counterpart. The Electrum Foundations is a strategic think-tank for its KISTA science park sponsor, charting future development paths.
6. Various existing projects and programs, from the B School's Entrepreneurship Center to the Arts and Sciences Science Technology and Society program and the University's Technology Transfer Unit provide partial potential bases for I School. For example Stanford's undergraduate STS program could renew its former colloquium series and inaugurate a distinctive innovation focused Ph.D. program in collaboration with innovation programs in the engineering school, drawing upon faculty expertise across the university as well as hiring dedicated faculty. A master's degree program might also be spun out of

the Transfer Offices expertise to prepare practitioners in incubator and science park management, technology and knowledge transfer and other innovation and entrepreneurship related fields. For some this would be an entry degree to professional practice while for others, after a significant internship period, it could be followed by a Ph.D degree, theoretically and research focused but also including policy and practice components. The objective is to train a new generation of innovation specialists and generalists, equally at home in the analytical and organizational elements of the field.

7. Conclusions

Stanford is virtually a unique case, the world leading entrepreneurial university, despite inhibited development. Issues that are seemingly resolved in one era about the university's entrepreneurial role may re-emerge in another as the model spreads to additional disciplines (from engineering and computer science to medicine and the biological sciences) and academic roles (from faculty and staff to Ph.D. students to undergraduates). During the past decade a series of translational research and entrepreneurial support structures have emerged to complement, if not marginalize the focal role of the university's TTO, the Office of Technology Licensing (OTL) OTL represented a significant advance in academic entrepreneurship, a shift from a legal patenting and protection model to a .proactive marketing and transfer model that accommodated but did not actively support start-up activity. On the one hand, these new initiatives, comprising a Stanford Innovation System (e.g. Spark, StartX, Biodesign, D-School) have moved entrepreneurship more deeply into the university's research and teaching activities while also formalizing and giving organizational structure to the university's informal relationships to Silicon Valley that largely take place through its alumni networks.

7.1 Future Research

While STS 186 undertook the systematic investigation of the Stanford Innovation System in Spring 2017; much remains to be done, both at the empirical investigation and policy implementation levels. For example, these innovative initiatives could usefully be expanded from their original sites into cross-university initiatives through a renewal of top down entrepreneurial leadership that characterized Stanford in an earlier era. It has been several decades since a leading academic administrator took entrepreneurial infrastructure as their main mission, even though a

serial faculty entrepreneur recently served as President. In the interim, faculty and students have led bottom up, with significant but limited lateral cross-fertilization and few collaborative projects with other area universities.

A series of “intermediate ties” that provide material support to innovation and entrepreneurship as a “gift” relationship in which a direct return is typically not required or expected, have been forged. These moderate ties underpin the weak ties of information exchange and overlay the strong ties of mentorship and sustained collaboration, with their affective implications (Granovetter, 1973). The internal and external relations of the various innovation entities are priority for future investigation, allowing us to address the question of the emergence of an “innovation system.” As an indication of networking potential, the 2017 study found that OTL was providing Spark with unlicensed disclosures as candidates translational research support. To what extent have similar collaborations emerged among other campus innovation entities?

Another issue is the development of links between Stanford innovation entities and external projects. Albats (2018) studies the digital platforms for knowledge and IPR transfer between universities and companies – while Stanford OTL is using one of such platforms, further research is needed to understand the role of such digital tools in a university innovation ecosystem. Jungblut (2018) is organizing a comparative study of Stanford Spark and the reception of its replica at Oslo University. Since Spark has inspired replicas at other universities e.g. Sao Paulo this study could be further extended and carried over to the D School which has been duplicated in Potsdam and elsewhere.

The above suggests a renewal of innovation during the past decade, rivaling such peaks as the 1970 founding of OTL and the 2009 founding of StartX, so that in the long term a relatively quiescent period in the interim may be reinterpreted. Indeed, it may be argued that there are too many exceptions to the rule, including initiatives not covered by this article, to declare a rule.

Although this paper has focused on support structures for entrepreneurship, a follow-on work could usefully address a plethora of Center initiatives, for example, the H-STAR Institute's Stanford Edinburgh Link collaboration and MediaX industrial liaison program, primarily focused on interaction with existing organizations, both firms and non-profit entities (Etzkowitz, 1998).

7.2. Structured Ambivalence

Clark (1998) developed the idea that the university attaining independence from government sponsors made it an entrepreneurial university. Since attaining a modicum of independence from government authority was a prerequisite for entrepreneurial activity, this study was relevant to the early stages of entrepreneurial transition of government dominated universities. The next step is a commitment to seeing that the knowledge developed within the university is put to use, especially in its local region. This can take a variety of forms, including developing internal capabilities for technology transfer and commercialization of research to playing a collaborative role in establishing a strategy for knowledge-based regional economic development and participation in initiatives to implement that strategy. The typical entrepreneurial university will contain, or be surrounded by, a penumbra of firms that originated from academic research, perhaps even sharing infrastructure. Courses may include private-sector internships, and firms may use academic resources such as libraries and computing facilities. This type of cross-utilization has proceeded farthest in newer industries, such as biotechnology, which already offer post-doctoral positions that approximate conditions in universities. As the university immerses itself more deeply in a wider range of commercial activities, new institutional relationships will almost certainly emerge--often with the encouragement and support of government.

There is a continuing dialectic between "leveraging your network" and passage through a more formal entrepreneurial support structure. No doubt, wisdom balances both in the tension of structured entrepreneurial academic ambivalence. At one end of the spectrum, there is the Thiel Foundations' offer of \$100,000 to students who decline or take a two year leave from a university's education and networking offer in favor of going directly for a start-up with the Foundation's networking support. Elizabeth Holmes, the founder of Theranos, who left Stanford after her first year, with a visionary idea for a medical device but without the advanced technical training to realize it illustrates the risks of premature entrepreneurship, as well as the differences

between highly regulated fields like medicine and more loosely supervised fields like software (Carreyou, 2018). On the other hand, software skills have migrated down to ever lower educational and age levels, making youth entrepreneurship more feasible. It is noteworthy that the most successful dropouts, like Gates and Zuckerberg, were software and business model innovators who went to elite private schools that provide much of the social networking and intellectual content of a US university education at an earlier age.

7.3. Stanford's Innovation System

Technology transfer at Stanford has evolved from an informal to a formal regime, including the opening up and resolution of an “innovation gap” that emerged from the double-edged sword of location in a region that had developed a strong entrepreneurial ecosystem. Learning from success is at least as important as the recently popular advice to learn from failure. In recent years, intellectual property generated in the world's leading entrepreneurial university located in Silicon Valley, the world's leading entrepreneurial region was subject to strikingly different fates. Stanford faculty distribute on a scale of technology transfer interest and experience: ranging from in principle, opposed to proponent, and in experience, from serial to neophyte entrepreneur. These entrepreneurial neophytes represent considerable commercialization potential but only if there is a business development support structure that goes considerably beyond traditional technology transfer services.

A laissez-faire university technology transfer regime held over-optimistic assumption that an entrepreneurially rich environment can provide all the necessary and sufficient ingredients to nurture a start-up. In other words, pull from the Silicon Valley did not require push from a Stanford University “innovation system.” Under these conditions, projects that were too early-stage to be licensed and required a start-up to move it forward either to the market or to the stage where an established firm would find it of interest to purchase, could easily be undertaken by serial faculty entrepreneurs, well integrated into the regional eco-system. However, less experienced faculty were largely left to fend for themselves.

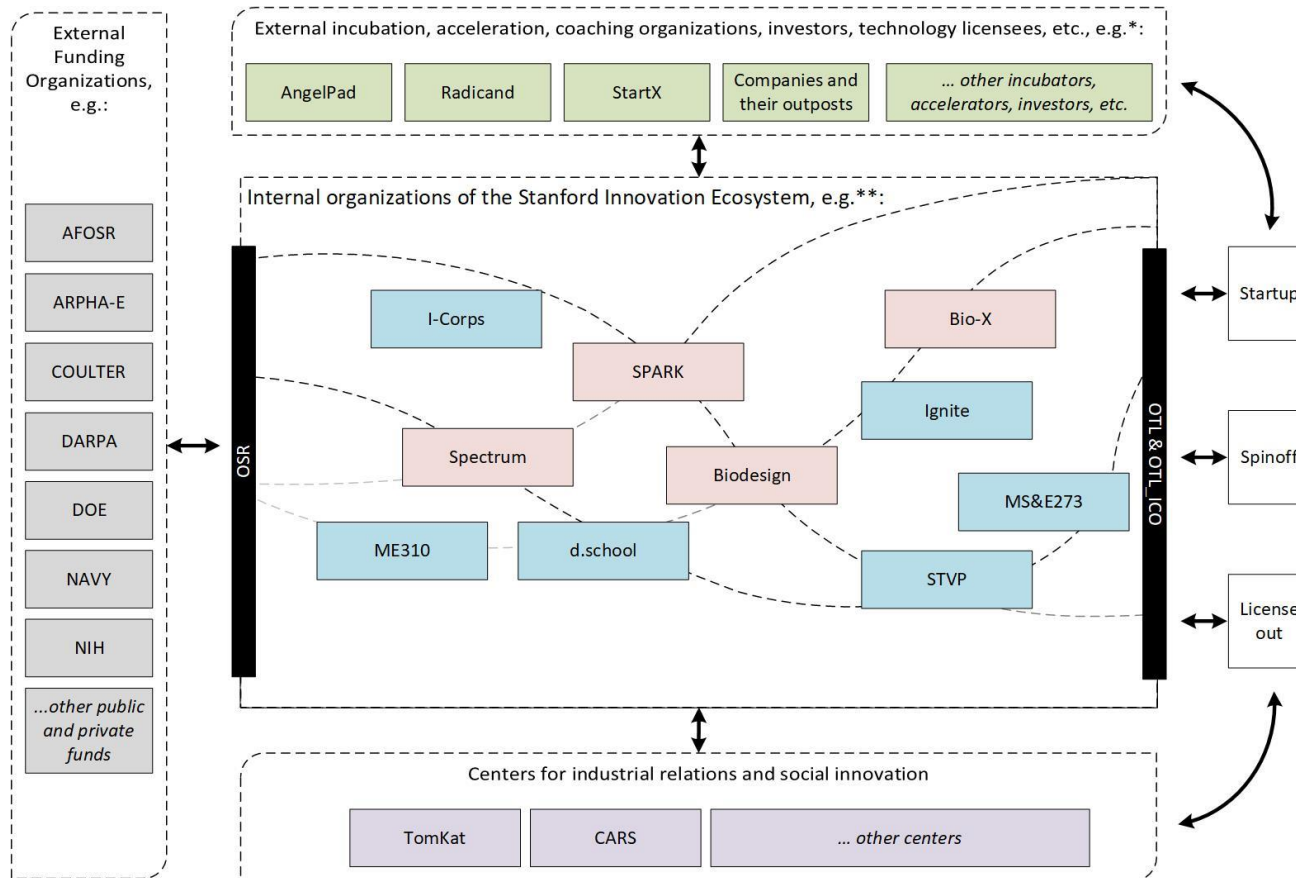
Stanford experienced arrested development in technology transfer and entrepreneurship due to an over-interpretation of the extent of informal relations between the university and Silicon Valley. This relationship was narrower than the university's technology transfer professionals expected, due to their focus on the university's relatively small but highly productive corps of serial entrepreneurs. An attitude of "if it's not broken don't fix" it took hold rather than the converse "If it's working well make it better". Due to Stanford's great success primarily based on its serial entrepreneurs, OTL was not under pressure from the university's leadership to revise its model until the student government's StartX project and various faculty initiatives, organized by successful entrepreneurs to assist their peers, appeared bottom-up, to fill the gap that aspiring student entrepreneurs and successful faculty entrepreneurs identified in the university's technology transfer regime.

These developments suggest that "the paradox of success," neglecting potential entrepreneurial activity, is being resolved at a new plateau, at least temporarily, and that Stanford's innovation system is expanding to produce even greater results than in the past. The "paradox of success" hinders a high-level of achievement becoming even higher through blindness to flaws that are obscured from observers as well as insiders. An increasing number of universities experience some or even all of these issues, suggesting the existence of an "epistemic drift" to an academic entrepreneurial format built upon previous missions as well as accepted as a mission in its own right (Thursby & Thursby, 2002). As innovation become institutionalized in novel organizational structures as well as linked to the teaching and research missions, the entrepreneurial university becomes a key element in the Triple Helix" model of innovation (Etzkowitz and Zhou, 2018). The entrepreneurial university paradigm, the key element in the Triple Helix, is yet at a relatively early stage of development, even at Stanford its most advanced exemplar.

Table 1. Simplified typology of entrepreneurial universities' archetypes, from Bronstein & Reihlen (2014)

Archetype	Research- preneurial	Techni- preneurial	Inno- preneurial	Commerce- preneurial
Main mission	Academic excellence	Technical expertise	Problem-solving service	Sector-specific hi-tech research
Main financial resources	Public and multilateral research funds	Multilateral and industry funds	Private sponsorships and public funding programmes	Own income from licensing
Transfer structures	Science Parks Research Centers	Incubators TTOs Informal and formal network with regional industry	Incubators Consultancy, training and start-up support centers	Incubators Technology parks High-tech R&D centers Spin-offs
Other main characteristics	Leads expertise in a specific field of research	Plays a major role in the regional economy, provides market-oriented education, has strong regional reputation and support	Has a flexible structure responsive to project opportunities, promotes interdisciplinary research projects	Emphasizes public relations and marketing to have a strong image
Illustrative cases	Stanford University	University of Waterloo	Copenhagen Business School	Twente University

Figure 1: Stanford innovation ecosystem



*For a Startup ecosystem of the Silicon Valley see Founder Institute, 2018: <https://fi.co/insight/the-most-comprehensive-guide-to-the-silicon-valley-startup-ecosystem-ever-created>

**The figure illustrates just a few of the organizations and programs at Stanford that constitute Stanford Innovation Ecosystem. The pathways of each startup, spinoff and technology are case-specific; the pathways on the figure are abstract examples. For specific case examples and particular pathways see OTL, 2017.

Table 2: Illustrative cases of the Entrepreneurial University in Theory and Practice

Entrepreneurship in:	Main points from the literature:	Illustrative cases: StartX Accelerator	d.school	Radicand	Biodesign	SPARK
	is varied in form, content and levels of education (Fayolle et al., 2016; Nabi et al., 2017; Bischoff et al., 2017; Klofsten & Lundmark, 2016)	proposes an experiential educational process supports less-experienced entrepreneurs	uses a cross-boundary interactive pedagogy		uses Stanford Design School Approach	provides entrepreneurial training (2-year program) e.g. through lectures, pitching and marketing practice during forums
Teaching	is possible only in a favorable context (Pittaway & Cope, 2007; Klofsten & Jones-Evans, 2000), where students can interact with entrepreneurs in particular (Brindley & Ritchie, 2000; Westhead et al., 2000)	draws business people into an educational process is part of Silicon Valley receives significant funding from Stanford university	is part of Stanford campus	is part of the Silicon Valley	was created in the framework of BioX is part of Stanford campus	is part of Stanford campus provides mentoring from industry experts

	is hard to measure in terms of outcome (Nabi et al., 2017)	"135+ Medical companies have gone through StartX Med, raising over \$920M+ in cumulative funding across all medical fields." (from StartX website)	claims that the interest is the journey, not the outcome		"Since 2001, the Stanford Biodesign Fellows and students from the Biodesign Innovation course have started more than 40 health technology companies from their fellowship/class projects, impacting nearly one million patients worldwide." (from Biodesign website)	62% of projects have been successful
Research	is the "third mission" of the university (Guldbrandsen & Slipersaeter, 2007; Siegel et al., 2007) and calls for applied and interdisciplinary research (Audretsch, 2014)	"StartX founders tackle big problems in every industry, from biotech, medical device, hardware, cleantech, and non-profit to consumer and enterprise IT." (from StartX website)	aims at developing solutions for the industry uses inter-disciplinary teams	aims at developing radical innovation	aims at teasing out unrecognized problems for solutions uses inter-disciplinary teams	receives project submissions from various Stanford's research departments
	takes many forms under the concept of academic engagement (Perkmann et al., 2013)	is also open to university researchers is a community of entrepreneurs, that provides mentorship and	was born from an informal initiative		is a network proposes fellowships	provides funding, training, developmental resources, mentoring and a large network to researchers

		education from experts and resources from partners	gathers faculty members and practitioners			
	mainly consists in commercialization of research results (Perkmann et al., 2013; O’Kane et al., 2015)	"accelerates the development of Stanford's top entrepreneurs" (from StartX website)	exposes academic firm founders to business reality		"2 out of 3 Biodesign Fellowship alumni are names as inventors on issued medtech patents" (from Biodesign website)	is open to professors, clinicians, postdoctoral scholars, and graduate students aims at moving projects “from bench to bedside” (from SPARK website)
	calls for an internal reorganization of the university (Siegel et al., 2007; Gibb et al., 2013)	is an "Innovation Organizer" at the university				provides a translational approach training to researchers
Innovation	makes the university a key actor in an entrepreneurship and innovation ecosystem (Guerrero et al., 2016; Mason & Brown, 2014; Bischoff et al., 2017; Isenberg, 2011)...	is successful because of the already existing university innovation system	has been replicated in other places (Postdam University, University of Cape Town, Ecole des Ponts ParisTech, etc.) involves many industrial partners	is a spin-off from Stanford University is part of the Silicon Valley	brings together faculty, students, and fellows from across Stanford University to create innovations with the power to change healthcare their location at the heart of the campus allows them to connect with leaders and access	has numerous relations with partners (Stanford’s OTL and research departments) and funders (Stanford’s Medical School, National Institute of Health, foundations)

					world-class resources and infrastructure in business, medicine, design, and engineering on a continuous and collaborative basis	has been replicated internationally (Brazil, Finland, etc.)
	...with an entrepreneurial champion in the university (Rice et al., 2010)	is the initiative of the student government	was created thanks to the key role played by the founder of Ideo design firm	was founded by a former executive director of the ME310 program at Stanford	was created thanks to the key role played by a medical school professor	was born thanks to the entrepreneurial success of a medical school professor

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