Preface: Triple Helix Innovation and Entrepreneurship

Henry Etzkowitz, Tatiana Pospelova, and Chunyan Zhou

Nobelist Linus Pauling proposed a triple helix to model deoxyribonucleic acid (DNA) in a paper, early 1953. However, the "double helix" model, mooted by James Watson and Francis Crick after "Lucky Jim's" sneak peek at Rosalind Franklin's iconic photograph 51 of its crystallographic structure, was sufficient to explain DNA. Society, however, is more complex than biology. University-Industry-Government (U-I-G) interactions and relationships provide an optimum methodology for entrepreneurship and innovation, moving research/knowledge into practice/use.

The triple helix model was derived from New England university-industry-government efforts, from the 1920's, to renew a declining industrial economy, convened by the region's political leadership. An academic leader with national presence, MIT's President Compton, played a key role in inventing a novel *pro-bono* venture capital organization, with support from the New England business and political communities. A parallel set of double helices: university-government and industry-university converged in Silicon Valley in the early 1990's. Bill Miller, sometime Stanford Provost, computer scientist and entrepreneur convened an academic-inspired, local government and business leadership supported organization, Joint Venture Silicon Valley that has produced the most dynamic version of the model, to date. Nevertheless, Silicon Valley is at risk, not only from competitors who will not surprisingly "raise their game," learning from the Valley and each other, but also as an unintended consequence of its very success!

Identifying the generative source of knowledge-based economic and social development is the core of the Triple Helix Innovation project to enhance innovation, entrepreneurship and regional development. Originating as a metaphor, inspired by an early 90's Conference sponsored by the Centro para la Innovacion Tecnologica, Autonomous University of Mexico (UNAM) on university-industry links, that openly recognized government as a key player. In the Mexican context, the proverbial "light bulb" turned on. Explicitly identifying the key actors in Boston's Route 128, an iconic regional innovation system, the Triple Helix has developed into an internationally recognized model, with predecessors (Sabato's Triangle) and variants (Quadra-helix, N-Tuple Helix etc.) Expanding from an analytic to a normative concept, Triple Helix is at the heart of the emerging discipline of Innovation Studies, and a guide to pioneering policies and practices at the local, regional, national and multi-national levels.

Government and industry, the classic elements of public-private partnerships, have been recognized as primary institutional spheres since the 18th century. The Triple Helix thesis is that the university is moving from a secondary, albeit important societal role in providing higher education and research, to a leading role on a par with industry and government, as generator of new industries and firms. The Entrepreneurial University, exemplified by MIT and Stanford, superseding and incorporating the Ivory Tower model, is an increasingly significant academic format, globally. As industrial society is superseded by a knowledge-based era, advanced knowledge is more expeditiously translated into practical uses, due to

its polyvalent nature as simultaneously theoretical and practical.

The lesson of the Triple Helix is to examine strengths and weaknesses and fill gaps in "Innovation Systems," whether publicly recognized as highly successful, declining or emergent. It provides clear guidelines and focuses attention and effort. The common objective is to develop an innovation strategy that neither rests on previous accomplishments nor fails to take action even in the face of parlous conditions and strenuous opposition to change. Knowledge, technology and organizational transfer that formerly occurred through publications, academic and popular; visits of varying length for advanced degrees, temporary positions that may last for most of a career, or professional tourism and migration are now driven by Internet and social media exchanges.

These virtual phenomena paradoxically increase rather than substitute for personal contacts and face-to face-collaboration. The growth of "landing sites" and co-working spaces in iconic innovation venues, like Silicon Valley, Berlin and London's "Roundabout," to host newcomers are one indicator of the velocity of interaction. Moreover, processes of technology transfer from theoretical findings that formerly took generations to accomplish now occur within the work life of the inventors, allowing them the possibility of participating in the invention and innovation dynamic, as well as the research and publication process.

The growing participation of highly educated persons and knowledge producing organizations in invention is a key argument for involving knowledge-creating institutions and their personnel more closely in the innovation process. Forged in different academic and national traditions, the university is arriving at a common entrepreneurial format that incorporates and transcends its traditional educational and research missions. The Academic Revolution, from the mid 19th century and ongoing, legitimized research as an academic mission. A Second Revolution arises from the confluence of several tributaries, including (1) the identification of useful as well as commercially valuable properties in the results of academic research; (2) the internal development of higher education institutions e.g. the development of research groups as "quasi-firms" and (3) external influences on academic structures, like the US Bayh-Dole Act of 1980, encouraging universities to take concrete steps to put research findings to use.

The Patent and Trademark Law Amendments Act (Pub. L. 96-517) instigated by the US university technology transfer profession, legitimize and clarifed the legal foundation for their enterprise. Moreover, it made explicit the tacit contract between the federal government and academia, instantiated in Vannevar Bush's 1945 *Endless Frontier* Report, commissioned by President Roosevelt, at his instance. Policies, practices and organizational innovations, like the country agent two-way flow model from practitioners (farmers) to academia (agricultural researchers), built upon the 1862 Land Grant Act, supporting universities oriented to agricultural and mechanical innovation, as well as the liberal arts. Indeed, one-third of the Massachusetts land grant was devoted by that state's legislature to support the development of the Massachusetts Institute of Technology as a public/private hybrid. MIT's founding purpose was to infuse regional industry with scientific expertise. Private, public good initiatives, like the founding of New York University promoted commercial training in that quintessential business locale. Such initiatives to translate knowledge into economic activity as well as addressing problems from society, posed to academia, have spread globally.

Triple helix and innovation systems

The theory of innovation systems argues that the flow of technology and information among people, enterprises and institutions is key to the innovative process; it comprises elements, structures, functions and occurs through "self-organization." On the other hand, the Triple Helix identifies three certain primary actors and forms the secondary actors (hybrid organizations) through university–industry–government (U-I-G-) interactions, and occurs through the initiative of "Innovation Organizers", identifiable individuals, groups and organizations, depending upon the conditions, needs and opportunities in a given region.

According to innovation system theory, innovation (eco)system and technology development are results of a complex set of relationships among actors in the system, which includes enterprises, universities and government research institutes. Although current innovation system theory has some terms that are the same as the Triple Helix, e.g. actors, relationship and interactions, its root concept is from "systemology or general systems theory," including formal sciences such as complex systems, cybernetics, dynamical systems theory, dissipative science, synergetics, catastrophe theory and applications in the field of the natural and social sciences and engineering, such as operations research, social systems theory, systems biology, human factors, systems ecology, systems engineering and systems psychology.

An innovation system is expected to evolve by self-organization, which usually relies on three basic ingredients: (1) strong dynamical non-linearity, often though not necessarily involving positive and negative feedback; (2) balance of exploitation and exploration; (3) multiple interactions.- In addition, self-organization is formed and maintained under the following four conditions: open system, far from equilibrium, fluctuation, and nonlinear interactions. By contrast, Triple Helix emphasizes the role of the Innovation Organizer (IO), whether individual or organizational, in taking leadership to bring diverse actors together in a common project. In nature and human society many phenomena are self-organized; but innovation is the result of a conscious and creative human collaborative effort driven by intentionality and imagination, exemplified by the Jobs and Rowling commencement addresses, Stanford 2005 and Harvard, 2011, respectively.

The essential differences between Triple Helix and Innovation Systems are shown in the following table:

Table1 Comparison of Innovation Theories

	Innovation System	Triple Helix

Origin	UK, Christopher Freeman's analysis of post-war Japanese innovation and enterprises (1986)	US, Henry Etzkowitz's research on MIT's role in regional innovation in early-mid 20th century New England (1993)
Primary actor (s)	Firm as primary actor, taking lead in product and process innovation, with various supporting actors: academia, government, intermediaries, financial institutions, in no special order. Each operates according to its special institutional logic.	Interaction among university–industry–government (U-I-G) is key to invention of new innovation formats with hybrid logics. An eco-system superstructure of venture capital, incubators, science parks etc., with Civil Society as a substrate, encourages bottom-up initiatives.
Academia's roles	Academia is viewed as an equal to other elements in the system.	The entrepreneurial university has a significant role in a knowledge-based economy.
Operation	The system structure (networks) determines the operation of the system as a coordinated, coherent and stable entity.	Interaction among relatively independent institutional spheres "taking the role of the other," produces novelty in an "endless transition."

Innovation System Theory orders its elements in sequence to facilitate passage of technology and information among enterprises, capital, innovation platforms, etc. When some single logic inputs' capacities are not strong enough to reach a "critical mass" or if the system doesn't meet the four conditions (openness, imbalance, non-linearity and fluctuation) for a self-organized evolution: innovation may not happen. Triple Helix focuses on "overlapping" spaces cross-cutting the boundaries of the institutional spheres. Actors with the ability to encompass multiple logics may perform various functions, individually and collectively. For example, capital may come from a variety of university, industry, government and other sources. They may create a public, private or mixed venture capital entity (like Israel's Yozma project, later transferred to Brazil by FINEPE on the sidelines of the 2000 Second International Triple Helix Conference in Rio de Janeiro), institutionalizing the arrangement.

Variants of the Triple Helix include a laissez faire version with institutional spheres strictly demarcated. However, this is largely a US ideological model, that obscures a reality of highly interactive U-I-G interactions at national, regional and local levels. In a statist version that is

government, military or Party directed; Civil society, to the extent that it exists, is an oppositional force to an authoritarian regime. For example, after the demise of Brazil's military regime, some of academic opposition became innovation organizers, instituting entrepreneurship training programs and innovation support structures, like the incubator, into Brazilian universities.

Nevertheless, large-scale one-off efforts, like the Manhattan project to construct the atomic bomb, have been accomplished through this top-down format. In the historical instance, even this military controlled project was inspired by academics and proceeded with voluntary industry participation, putting aside anti-government ideology for the duration of a national emergency. The temporary wartime Triple Helix transformed US universities, making large-scale research enterprises that were an anomaly in the pre-war into a commonplace in the post-war. More importantly, academic scientists, who had opposed government funding of research even in the depths of the depression, fearing government control, reversed field after the war. Having led the establishment of the wartime Office of Scientific Research and Development (OSRD) Agency, scientists realized that if they were basically in control of its research enterprise offshoots and dispensation of funds; they had little to fear from government and changed their attitudes and behavior. They henceforth saw government as an ally of a Science that could "deliver the goods," whether for military victory or peacetime objectives. The subsequent goal of US, and indeed global innovation policy proponents, has been an attempt to recuperate and/or realize that vision.

The Triple Helix started from observation of win–win development of university and its region in a co-evolving relationship. It is not a "system" conception but is an "open" innovation concept, per se. Therefore, while an innovation ecosystem that arises as the result of a particular triple helix configuration cannot be duplicated in its precise format, for example, Silicon Valley, a triple helix with three primary actors and multiple secondary actors can be replicated worldwide as a *universal innovation model*.

Science, Technology and Society (STS 186)

Materials for this book were collected for the Seminar "Innovation and Entrepreneurship: A Triple Helix of University-Industry-Government Interactions" at Stanford University. The editors hope that this volume may also find use in innovation, entrepreneurship and intellectual property policy modules in universities worldwide. Its topics may also be of interest to teachers in company universities and in Innovation Agencies such as Brazil's FINEPE Venture Capital and Sweden's VINNOVA's Triple Helix training programs. Hopefully, it may also find its way to technology transfer offices, science parks, incubators and accelerators, onto the Director's bookshelf. It may be useful to be loaned out to innovation practitioners entrepreneurs, and management personnel, seeking to better understand the theory, policy and practice of entrepreneurship, innovation and new ways of technology development.

The book is divided into Sections associated with the course syllabus (See Appendix):

- Innovation and Entrepreneurship
- Stanford Innovation System
- Silicon Valley Trajectory and "Wannabees"
- Policy Implications

The first part focuses on the conceptual basics of innovation and entrepreneurship, taking off from Harvard's Kennedy School Prof. Calestous Juma's interpretation of Joseph Schumpeter's classic account of individual and collective entrepreneurship and "creative destruction." This is followed by Fuji CEO Komori's account of how his firm averted Kodak's fate, and related concepts.

The second part focuses on Stanford University. It is often said that universities rarely closely examine themselves. However, this section takes off with an excerpt from the co-founder of institutional economics, Thorstein Veblen's *Higher Learning in America,* apparently based on his early 20th century Stanford experience, including observations on its student culture. This part primarily treats Stanford's early entrepreneurial efforts that contributed to the technological development of northern California and industrial interactions that raised the level of its academic programs, especially in engineering. Over time, attracting PhD's to its engineering faculty, along with an infusion of industrial technology into its teaching and research programs, encouraging research and training in collaboration with firms, created an innovation capacity. These achievements enabled faculty and student collaborations, like the one among Professor Terman and his students, Hewlett and Packard in the late 1930's. Together, they invented and spun off technical innovations that found a market in a complementary motion picture industry in southern California, seeking enhancements to its technology. Thus, the Disney firm purchased the Stanford originated oscillators to enhance the sound quality of *Fantasia* in specially configured theaters, with Dolby-like apparatus.

This historical background is complemented by analysis of the university's contemporary innovation infrastructure. Our Seminar research project is on a "Stanford Innovation System" that has, in recent years, expanded from an iconic Office of Technology Licensing (OTL), spun off from the university's contracts and grants office in 1970. Its founder, Niels Reimers, acted on the premise that an organized effort to market the university's intellectual property could produce significantly greater results than disparate individual efforts. Mechanical Engineering (ME 310) a cross-disciplinary prototyping course, involving industry customers, funders and users, seeking out-of-the box solutions from student collaborations, originated more than 40 years ago through a collaboration between an engineering and an art professor.

A plethora of recent initiatives with names like Radicand, Start X, Bio X and D School build upon and fill gaps among these and other early initiatives such as the Stanford Research Park, the progenitor of the international science park movement, institutionalized in the International Association of Science Parks (IASP) and the American Association of University Research Parks. Our seminar study is modeled on a study of the Chalmers Innovation System, led by innovation research colleagues Professors Merle Jacobs, Lund University, and Mats Lundqvist, Chalmers University of Technology, undertaken at that Swedish university. STS 186 aims to produce and publish a comparative analysis.

The impact of Stanford on the creation and development of Silicon Valley is treated as well as industry and government's influence on the university's development and stature. Here, we explain university-industry interaction, conflict of interest and obligation, intellectual property policy, the technology transfer process, public and private venture capital etc. The Silicon Valley Trajectory, "Wannabees" and Policy Implications Sections examine innovative projects in different parts of the world: the conditions in which they operate and the courses of action they have pursued in response to their special circumstances and opportunities. Special attention is paid to the experience of Silicon Valley-like phenomenon in other countries, e.g. China (Linye, Shandong) and Russia (Skolkovo, Moscow).

Overall, this volume treats the various stages of theoretical and practical principles of entrepreneurship and innovation. It provides a desktop tool for students, researchers, lecturers of entrepreneurship and innovation policy in engineering management, economics of innovation and Science, Technology and Society. It also offers ideas, assistance and models that may be helpful to innovation consultancy practitioners, firm strategic planners, government policy makers and analysts. Start-up entrepreneurs, emerging from the early stages of firm-formation, with its laser focus on lift-off, to the follow-on stages of acquisition or IPO, may find it helpful to gain a broader innovation perspective and purview, appropriate to either an independent firm or a seeker to be acquired.

The authors invite readers and users of this volume to let us know their experiences with the materials provided and of any related ventures of their own. We may be reached at henryetz@stanford.edu, tatiana7pospelova@gmail.com,