

Regional Innovation Initiator:

The Entrepreneurial University in Various Triple Helix Models

Henry Etzkowitz and Chunyan Zhou

Abstract: This paper elucidates the roles of the entrepreneurial university in the triple helix of university-industry-government, through “field and circulation” concepts. Field explains independence and overlap among the helices; circulation represents their dynamic interaction. The premise of a successful triple helix is that at least one helix can supply a driving force to initiate regional innovation. Entrepreneurial universities play diverse roles in university-pushed, government-pulled and corporate-led innovation, with different initiators in various triple helix models.

Key words: entrepreneurial university, triple helix field, triple helix circulation, non-linear technological innovation model, regional innovation

Introduction

The University is undergoing a cultural transformation to play a significant role in knowledge-based society as an entrepreneur, promoting regional development. An entrepreneurial university is more than the creation of interface mechanisms between university and industry such as a liaison or transfer office to assist existing firms or create new ones. Infused with entrepreneurial attitudes and strategic vision; the entrepreneurial university collaborates with other actors to further regional innovation. Most fundamentally, the faculty view their research and teaching in a new light, looking to contribute to technology transfer and firm-formation as well as to education of students and advancement of knowledge.

Triple helices emerge with rise of the university to equal status with the economy and polity and as knowledge-based societies embed academia, government and industry in lateral relationships. The University has expanded its mission, since its medieval inception, from its original task of preservation and dissemination of knowledge, to production of new knowledge and more recently to putting knowledge to use. Other transitions include the integration of humanistic studies in the 16th century and the university becoming the institutional home for the empirical social sciences in the 20th century (Lazersfeld, 1961). Each transformation invokes a “game of legitimation,” with new missions conflated with old, such as economic development and research, and concepts formulated to place change in a new light.

This paper adapts “field and circulation” concepts from the physical and biological sciences to delineate the “operating system” of the triple helix. It depicts the roles of the

entrepreneurial university in societies that differ according to which helix is the leading innovation actor. MIT and Stanford exemplify a U.S. “university-pushed” triple helix in contrast to a “government-pulled” triple helix in China and industry-led triple helix models in other countries. Regional triple helix innovation is also a function of academic goals and objectives, trust among university, industry and government and the strength of local organizing and initiating capabilities. Nevertheless, knowledge spill-over increasingly occurs through commercialization of research results on campus, irrespective of societal or academic differences.

I. Invention of the Entrepreneurial University

An entrepreneurial university is the generative principle of university-industry-government interactions as a source of innovation. Ability to act as an independent entity is a necessary but not sufficient condition (Clark, 1998). The key elements of the entrepreneurial university model are: a research base with commercial potential, a tradition of generating start-ups, an entrepreneurial ethos on campus, policies for defining ownership of intellectual property, sharing profits and regulating conflicts of interest and participation in regional innovation strategy.

Balancing teaching, research and service in a creative tension, an entrepreneurial university has three primary characteristics:

- 1 *Entrepreneurial activities are accepted and systematically supported*
- 2 *Interface mechanisms e.g. a technology transfer office and corresponding achievement*
- 3 *Significant numbers of staff members form firms, which can generate income to support university research and other activities*

Knowledge spillover from universities promotes regional development, through commercialization of research and provision of new firms, human resources and new ideas.

Entrepreneurship has become part of the academic research ethos. The importation of a strong research ethic from Germany, combined with a lack of resources to support research, created an impetus to entrepreneurship in U.S. universities in the mid-19th century (Jencks and Riesman, 1968). An entrepreneurial dynamic was created as faculty sought support, at first from their university and then from foundations and industry in the early 20th century. Capitalization of knowledge occurred both in private and public universities due to several factors: the potential of research for use, the development needs of regional industries, including agriculture, and the interest of universities in regulating the commercialization process in order to protect their reputations, since many discoveries had health and medical implications (Apple, 1989).

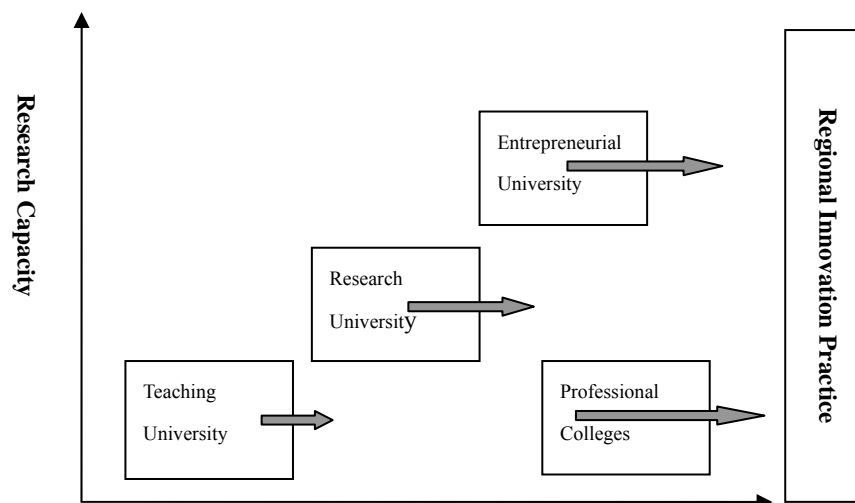
With the entire faculty incentivized, a faster rate of innovation is induced as findings from research spread more rapidly into teaching since the two activities are conducted by

the same persons. Elaborate academic hierarchies, with senior professors responsible for their junior colleagues' support, break down when all faculty members, including the most junior, have responsibility to formulate projects and seek funding (Storr, 1953; 1968; Oleson and Voss, 1979). The elimination of the Docent position in U.S. research universities in the late 19th century and the introduction of junior professors in Germany in the early 21st century are manifestations of this trend toward equality, in title as well as responsibilities, from opposite directions.

There are several phases to develop an entrepreneurial environment; some may already be in place through the transition from a teaching to Research University:

- a *Control of strategic direction, physical infrastructure, and the ability to fund raise and tap alumni and public support (Goddard, 2004);*
- b *Focused fields with conjoint theoretical and practical potential (Viale and Etzkowitz, 2004);*
- c *Technology transfer capabilities to close the gap between invention and innovation (Owen-Smith and Powell, 2003)*

University enterprise development increasingly follows an assisted linear model with various forms of informal and formal help provided, from introductions to venture capitalists to packaging a firm, with or without the inventor (Etzkowitz, 2006). Interface organizations also play a reverse linear role, introducing universities to external problems, sources of knowledge and organizations seeking academic resources. University development is non-linear as regional academic clusters evolve in an entrepreneurial direction (Figure1).



Entrepreneurial universities have arisen from strikingly different academic missions, even with the “first revolution,” research, occurring simultaneously with the “second revolution” of economic and social development. An entrepreneurial mode is typically an overlay on a research university but it can also be a strategy for development from a

teaching university, with the phases accomplished simultaneously or even in reverse order to the usual progression. For example, the State University of Rio de Janeiro Friburgo campus began with a Ph.D. programme in IT, accompanied by an incubator, in an innovative academic and regional development strategy.

Various types of institutions of higher education contribute to regional innovation in different ways. Universities have different missions: the teaching university is based on education and dedication to the personnel market; the research university engages in production of knowledge, as well as teaching; the entrepreneurial university encompasses teaching, research and service for society. In practice, any university has potential to assist industrial development, irrespective of level and mission. Only the entrepreneurial university has the capacity to complete a circulation of trilateral cooperation. It transcends “professional colleges” to contribute to high-tech and industrial innovation at a higher level.

University commercialization focused on applied research and short-term application, subordinate to existing industry, is neither an inevitable development nor the most desirable goal (Faulkner and Senker, 1995; Slaughter, and Rhodes.1997). Although some local academic institutions may usefully perform these tasks, the university has a more significant function to perform as a source of new intellectual fields and regional industrial renewal (Figure2). The potential for enterprise development is broader than the natural sciences and engineering; the social sciences have been a significant source from survey research, focus groups and econometrics. Academics may play a role in firm formation in ways compatible with research and training through generous leave policies and a “one fifth rule” regulating consultation; allowing an advisory but not an executive position while holding a full time academic job.

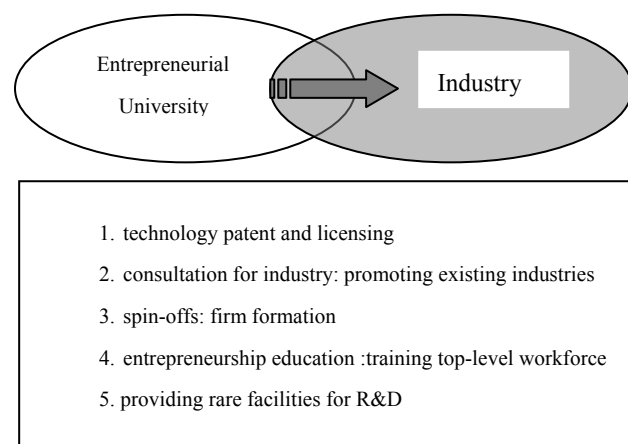


Figure2 Entrepreneurial University’s Roles to Industry

Since it is better to anticipate issues rather than waiting for controversies to erupt, Frank Rhodes, former President of Cornell University, has suggested a protocol for university-industry-government partnership based on “...respect [for] the integrity and interests of all the institutional partners...” and participants, including students (2001:

245). Several of his suggestions, such as general templates within which specific arrangements may be negotiated, are already in practice. In an iterative process, universities inquire about peer practices and adjust policies, such as royalty rates, to balance incentivizing inventors with keeping good relations with firms.

There is a continuing debate over which aspects of academic research should be public and private (McSherry, 2001; Bok, 2003; Mowery et.al. 2004; Washburn, 2005; Leydesdorff and Meyer, 2006). Entrepreneurial science is controversial; it has been criticized as a socially inefficient ‘privatization’ of academic research and as a threat to the ethos of science itself. Other analysts suggest a “more the more” thesis with patenting and publishing mutually reinforcing one another (Blumenthal et. al., 1986). Stanford played a significant role in creating Silicon Valley but it is also a leading university in the humanities and the social, biological and physical sciences.

Despite incorporating seemingly contradictory tasks, the university has maintained a core identity. Centripetal forces have outweighed centrifugal ones through organizational innovation in the form of departments and centres; the former allowing multiple professorships in a single discipline, the latter encouraging cross-disciplinary hybridization. Entrepreneurial activities enhance traditional missions contrary to the thesis of academic decline (Readings, 1996). Keeping the critical, investigative and entrepreneurial functions together in the same institution generates new disciplines such as environmental science as well as financial resources. Stanford has a center for the study of conflict of interest in its Medical School and a technology transfer office that set the model for the profession. Just as research emanates from teaching; new research ideas may arise from entrepreneurial activities, as Vannevar Bush found with his consulting practice (Bush, 1970).

The internal structure of the university is transformed by multiple tasks, initially at the administrative penumbra and then in its educational core. Teaching is expanded from lecture and discussion to a project mode in which participants exchange ideas and formulate a common objective, with the teacher serving as guide. Universities have developed technology transfer capabilities and extended their teaching from educating individuals to shaping organizations through entrepreneurial education and incubation. University incubators educate a group of people to act as an effective organization. The Popular Cooperative Incubator in Brazil, originated by technology transfer professionals with a social vision, extended organizational education beyond the formation of high-tech firms to excluded populations (Etzkowitz, Mello and Almeida, 2004). The university’s new economic and social development mission thus connects back to its original teaching mission.

The university is a natural incubator; providing a support structure for teachers and students to initiate new ventures: intellectual, commercial and conjoint. The university is also a seedbed for new interdisciplinary fields and new industrial sectors, each cross-fertilizing the other. A self sustaining dynamic of economic and social development is in part based upon traditional academic features, since education is a reproductive process with a high rate of people flow, making the University a propitious site for

knowledge-based innovation. Students are a perpetual source of potential inventors. As they matriculate they bring new ideas with them and as they graduate, they take them to other venues (Slaughter et. al., 2002).

A university education should include training in various disciplines, as well as specialization, with a few key topics universal. As Cardinal Newman put it, "...if the various branches of knowledge, which are the matter of teaching in a university, so hang together that none can be neglected without prejudice to the perfection of the rest...(Newman, 1959:102). Just as graduates should be able to write an essay expressing their personal thoughts and a scientific paper, placing evidence against hypotheses; so should they write a business plan, setting forth an idea for a new project and a test of its viability. Conversely, MIT feared that if its students were only trained in narrow technical disciplines; they would end up working for people with a broader education: Harvard graduates would become managers; MIT graduates their employees. Thus, MIT built strong humanities departments, especially in fields relevant to technological issues, on the premise that it was necessary for its graduates to have a broad liberal education in order to become effective leaders.

II. Entrepreneurial University in a Triple Helix

Transformation of academia from a "secondary" to "primary" institution is an "expanding universe" phenomenon rather than a zero sum game. The university's enhanced status is based on its ability to develop new techno-economic paradigms and tease out technological and economic implications from research. Thus, "the knowledge industry in modern societies is no longer a minor affair run by an intellectual elite, an activity that might be considered by pragmatic leaders as expendable; it is a mammoth enterprise on a par with heavy industry, and just as necessary to the country in which it is situated" (Graham, 1998). Academic expansion is a reciprocal cause and effect of the growth of increasingly knowledge-based societies (Machlup, 1973).

The University evolves from an individualistic to a holistic perspective as its missions expand. Research shifts from a relationship between individual teachers and students to a web of relationships among the research group members. The academic research group has many of the attributes of a business firm; with the group leader as entrepreneur, collecting resources and coordinating activities. Thus, it is a relatively short step from quasi-firm to firm when precipitating factors are in place (Shimshoni, 1971). Initially focused upon a particular technology invented at the university or service to a local firm; over time, the university expands the scope of its service mission and plays a broader role in regional development, often acting together with industry and government.

Academic entrepreneurship is a training ground and precursor of spin-off activity (Vollmer, 1962). Academic scientists, who formerly viewed themselves as operating at a great distance from business, realize that the manager of a research group is an entrepreneur. They view themselves as possessing the organizational and leadership skills necessary to run a small or even mid-sized enterprise. Undertaking a start-up appears less formidable, with the recognition of entrepreneurial science and business as virtual mirror images. Thus,

the incipient entrepreneurial element in the professorial role is amenable to expansion should the opportunity arise.

There is a progression from advisory to active roles. As they participate in the periphery of science-based firms, through membership on a Scientific Advisory Board, professors become knowledgeable about the interface between research and business.¹ Dr. Arthur Kornberg (1995), a Nobel Prize winner and self described pure academic, nevertheless became enthralled and involved in a bio-tech start-up as did Joshua Lederberg, another Nobelist and sometime critic of university firm formation. Academic scientists have become increasingly sophisticated connoisseurs of intellectual property, even if they choose not to be involved in firm-formation. Some have become serial entrepreneurs, moving between university and firm as they seek scientific advance and business success.

The financing gap in the early phases of firm-formation from early-stage technology, the so-called the “Valley of Death,” has been partially filled by academics who have earned funds from ventures and by alumni who have become successful entrepreneurs. Dual academic and business experience provides an understanding of technology and its commercial potential. Thus, some serial entrepreneurs have become “university angels,” with the ability to judge both technical and market potential, and invest in their colleagues start-ups (Etzkowitz and Pique, 2005). They may be willing to overlook lack of revenues, customers and even a clear business model that are requirements for business angels, who, not surprisingly, require clear business signals, such as a revenue stream, in order to invest.

Interviews with scientists conducted in a late 1970’s California photovoltaic start-up, identified scientists who did not fit sociological definitions of academic or industrial scientist (Merton, 1979). They were not interested in publication; their goal was patents, neither did they suffer “role strain” of corporate scientists making the transition from academia (Kornhauser, 1962). These researchers were “entrepreneurial scientists” (Etzkowitz, 1983) and participated in decision making as backers of the firm, with funds earned from stock options in the semi-conductor industry. In later discussions with Rosalba Casas and her colleagues at the National Autonomous University of Mexico (UNAM), it became clear that university-industry relations could not be understood in isolation. University and industry in Mexico primarily interact through their links to government; thus its role was highlighted. A triple helix of university-industry-government interactions was the resulting insight.

Elements of Marx, Weber and Simmel’s ideas inform the triple helix of interconnected and partially autonomous institutional spheres. Simmel’s analysis of triadic relationships is given an institutional cast: university, industry and government each may act as a ‘tertius gaudens’ instigating innovation (Wolff, 1950). Marx laid the groundwork for a theory of differentiated social spheres in analyzing the separation of a capitalistic economy from the feudal social relations of medieval society. The shift from the household economy depicted by Aristotle, with production moved from home to factory and work separated from family life was a key event (Marx, 1973). Marx also posited science as source of the future economy, based on a single crucial instance: Perkins research on dyestuffs in England

¹ Prof. Irving Weissman, Stanford University Medical School (2005) Interview with Henry Etzkowitz

developed into an industry in Germany.

The growth of science-based technology, from the 17th century, intersecting with the emergence of independent institutional spheres in the 18th century, founded a new dynamics of innovation. These two dimensions came together in the creation of the Research University in the 19th century, incorporating experimental science. The teaching laboratory was invented, scaling up the integration of research and teaching, including research with practical implications, as the university gained autonomy from other social spheres (Rossiter, 1975). These twin developments augured the transition from a society based on vertical stratification in the pre-modern era to one increasingly based on horizontal relationships among inter-related institutional spheres.

The vertical hierarchies of the pre-industrial and industrial eras, the first based on tradition, the second on expertise, are gradually superseded in the transition from an industrial to a knowledge-based society. A renovation in social relations occurs comparable to the one that took place during the transition to industrial society. The primary factor in each of these transformations was the role of knowledge in society. In feudal society, the most important knowledge was the lore of tradition, the taken for granted relationships of superiors and inferiors in society and the obligations that each owed to the other whereas in industrial society, it was the erudition of bureaucracy, how to carry out specific tasks under supervision, the understanding of the basis of willingness to accept orders from above, on the one hand, and the capacity of management to give relevant instructions, on the other (Weber, 1947).

Three independent dimensions: economics, politics and status, belief in the reality of social differences based on any criteria, co-exist in a relationship of mutual causation. Political power generates economic wealth and the ability to live off politics; while ideas may be translated into economic and political power. Ethical ideas associated with Protestantism were an impetus to the rapid development of economic activity in the West in addition to accumulation of technological forces (Weber, 1958). Other bases for innovation and societal transformation have since been identified.

III. Conceptual Foundations

University-industry-government interaction in knowledge-based societies is increasingly recognized as the source of new models of regional innovation that drive the translation of scientific and technical advance into economic activity. To describe how a triple helix works, we propose three concepts: non-linear innovation framework, field interaction and circulation as the foundations of a triple helix research programme. A triple helix has a static characteristic in which three spheres are independent and overlap each other and each helix has an internal core and external field space. A dynamic image is depicted: in the vertical dimension each helix develops independently; in the horizontal dimension they form an interactive circulatory system.

3.1 Non-linear and Net-like Innovation

Innovation embodies the total process of the application of a new idea (Schumpeter, 1911). Following Schumpeter's definition, "An innovation in the economic sense is accomplished only with the first commercial transaction involving the new product, process, system or device, although the word is used to describe the whole process." (Freeman, 1982) Freeman identified four different types of innovation: incremental, radical, technological system innovation and technological revolution or change of techno-economic paradigm (Freeman, 1986).

A linear innovation model influenced by *Science: Endless Frontier* prevailed in the 1950s and 1960s (Godin, 2006). It neatly described the commercialization of science as a process moving from →technology inventions → R&D → production → marketing products. The critique of this model is that it oversimplified the actual innovation process and did not adequately reflect the increasingly complexity of contemporary technological innovation. Kline and Rosenberg's (1986) chain-link model of innovation depicted the innovation process as much more complex, recognizing that the academy does not produce knowledge blindly; nor are firms its passive recipients. Nevertheless, it still kept the linear order, although admitting interactions and feedbacks, reflected by a chain with arrows.

Contemporary innovation is increasingly complex with multiple starting points and approaches. In the face of skepticism from the military sponsors of artificial intelligence research in the mid 1970's, the head of the computing office in the Defense Advanced Research Program (DARPA) of the U.S. Defense Department concluded that it would be to the mutual advantage of all for the academic researchers to take an interest in their sponsors practical problems. "...the shift will give the university research groups an engineering arm, a marketplace, customers, users. [That] integration will strengthen the basic work because there will be more feedback from real tests of the big new ideas..." (Waldrop, 2001:405). The author of this statement, a psychologist involved in the early development of computer science as an academic discipline, the redoubtable J.C.R. Licklider of Internet origin fame, joined DARPA from MIT, after a stint at Bolt, Beranek and Newman (BBN), a consulting and research firm (Hafner and Lyon, 1996).²

In his early work, Schumpeter strongly emphasized the key role of the entrepreneur in seizing technological and market opportunities as well as steering the innovation process. However, entrepreneurs in contemporary society might be professors, engineers, researchers or inventors, businessmen, and even some politicians. In Sweden, where individuals are unlikely to take an initiative without group support, there is a tradition of collective entrepreneurship. Indeed, a collective entrepreneur is always a salutary impetus for a knowledge-based firm that requires both technical and business expertise that is unlikely to reside in a single person.

² BBN was considered the "third shop," an equal of Harvard and MIT, in the Cambridge U.S. artificial intelligence community (1986) Prof. Marvin Minsky, Electrical Engineering and Computer Science, MIT, Interview with Henry Etzkowitz..

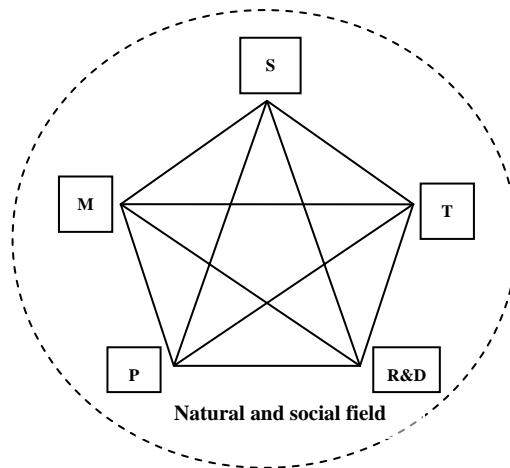


Figure3 Non-linear and Netlike Pentagonal Model of Technological Innovation

Figure3 describes a non-linear and netlike innovation model that may begin from different starting points among science, engineering, R&D, production and marketing activity. For example, John Bardeen, one of the inventors of the transistor, “believed it made sense to look first at the technological base and then work on developing the corresponding science, rather than...[the other way around] “finding something in science and then looking around for applications” (Hoddesson and Daitch, 2002) Thus, an innovation may take place in the order of market→technology→science→technology→R&D→ production→ marketing or marketing→technology→science→R&D→ production→ marketing and any other way. Although the netlike model draws from micro- innovation, it can also reflect macro-innovation at the regional level where innovation is the mixture of all the innovation activities, which can be taken on by the same or different institutions.

3.2 Triple Helix-Field Interaction

The triple helix model posits three spheres, overlapping and interacting freely, with each “taking the role of the other,” producing hybrid organizations such as the science park, spin-offs, university-run enterprises and the incubator from these interactions. However, this model lacks precise indicators and measurement techniques. We use field theory from physics to develop a method for triple helix analysis, drawing upon a study of the nature of interaction between science and technology (Zhou, 2001).

Triple helix field interaction depicts the helices as a model with an internal core and external field space (Figure4). It helps explain why the three spheres keep a relatively independent and distinct status, shows where interactions take place and explains why a dynamic triple helix can be formed. The university can play industry’s role but not as a true enterprise, and the same for industry and government, while persisting as relatively independent spheres. An institutional sphere may lose its distinct character if it can not maintain its relative independence. It is also very difficult for highly dependent spheres to interact in the external field space, since the confusion of functions or roles inevitably

results in a disordered system.

When a field exists with energy around it; the field can act upon its surroundings. In an electric field, for example, the action on charges put in a field space is represented by the force of an electric field. The endured force per unit charge is defined as the intensity of the electric field, describing the strong or weak degree to which the field influences the charge. Thus, intensity of field is introduced, indicating the degree to which helices promote innovation activities. If E represents the total field intensity, and E_u , E_i , E_g respectively represent the intensity of university, industry and government actions, then $E=f(E_u, E_i, E_g)$, the result of the interaction (Figure5; Zhou, 2002).

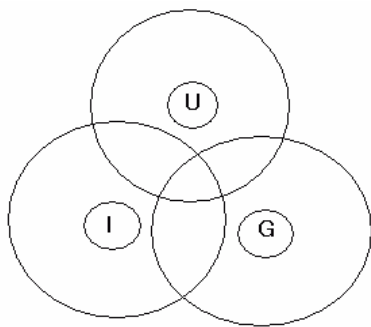


Figure 4 Triple Helix-Field Interaction Model

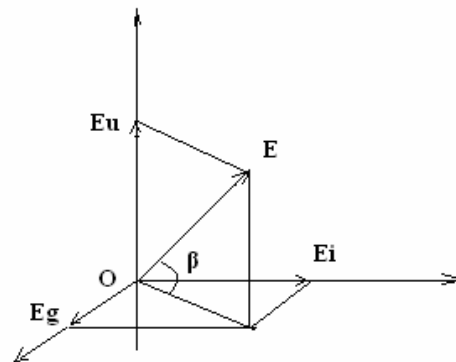


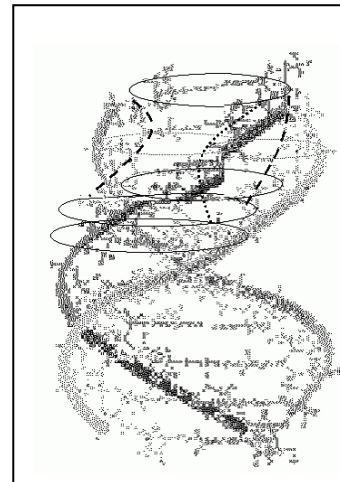
Figure 5 The Intensity of Triple Helix Field

Field theory illustrates the importance of limiting the transformation from laissez-faire to overlapping spheres or too sharply reducing a statist model, to retain each sphere's independence while facilitating interaction. For example, if government is too strong, then a statist model might be formed. If the interactions among three helices are too weak, there is not enough force to integrate them, leading to a laissez faire situation.

Analyzing lost or weak factors, “gaps,” and filling them helps create balanced triple helices. A regional innovation organizer (RIO) and regional innovation initiator (RII) exercise different yet related gap filling capabilities. A RIO provides convening capabilities while an RII must have sufficient prestige and authority to aggregate resources and initiate an enterprise. The governors of New England convened regional academic, industrial and governmental leadership in a series of meetings from the late 1920's but it was Karl Compton, the President of MIT, who eventually catalyzed ideas for science-based firm formation and mobilized regional leadership to act (Etzkowitz, 2002). Conversely, when the New York Academy of Sciences convened a series of meetings of representatives of university, industry and government to support knowledge-based economic development, in the mid 1990's, it was unable to make the transition from RIO to RII and take discussion into action.

3.3 Triple Helix Circulation

Knowledge capitalization has various sources in industry, universities and government institutes. When knowledge is transformed into capital; persons from any originating organization may be potential entrepreneurs and firm founders. A Triple Helix in which each strand may relate to the other two can be expected to develop an overlay of communications, networks, and organizations among the helices” (Etzkowitz and Leydesdorff, 2000). The figure they gave also reflects the spirally developing triple helix: a synthesis of evolution in the vertical axis and circulation in the horizontal.



Triple helix-field interaction sheds light on why there is circulation, but it does not show what factors participate in it and how it works. Figure6 depicts a triple helix circulation that occurs on “macro and micro” levels. Macro circulations move among the helices; while micro circulations take place within a particular helix. The former create collaboration policies, projects and networks while the latter consists of outputs of individual helices.

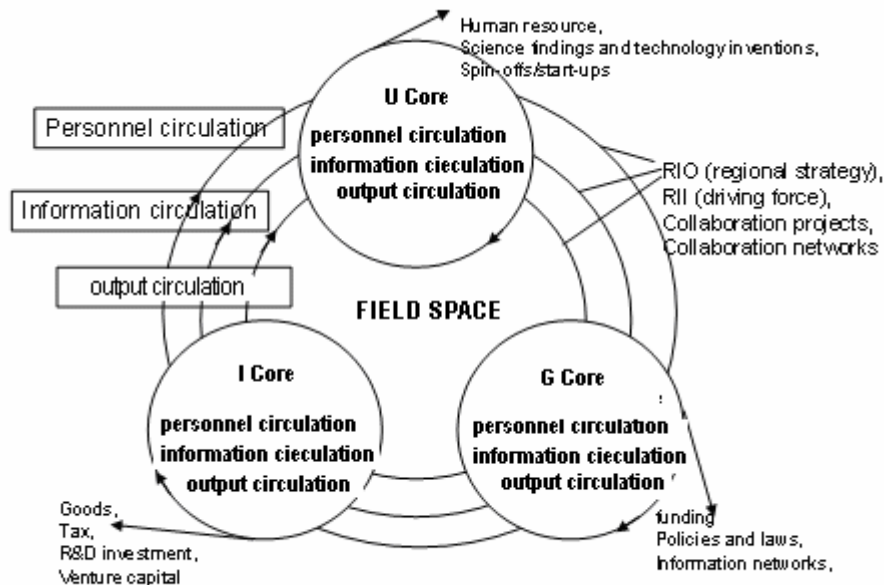


Figure6 Triple Helix Circulation

❖ Personnel Circulation: People Flow

Personnel circulation around the triple helix has been called a “revolving door”. The American sociologist C. Wright Mills (1958) strongly criticized this phenomenon as resulting in corporate dominance of government and untoward military influence in

industry. People flow may also introduce ideas from one sphere to another: sparking collaborative projects and promoting cross-institutional understanding. Indeed, lack of circulation of elites may be a cause of blocked development in countries whose leadership has nowhere to go once they complete their term in office (Dziseh and Etzkowitz, 2006).

At least three types of circulation can be identified: (1) Unidirectional or permanent movement from one sphere to another. On the university-industry interface, high-tech-firm entrepreneurs who were university professors exemplify the flow from university to industry e.g. A. Bose from MIT to his acoustical firm, while retaining a tie as adjunct professor. Reversely from industry to university, the archetypal figure is the co-inventor of the transistor, Shockley, who entered Stanford University as a faculty member from industry in 1963. (2) Double life or holding simultaneous significant positions in two spheres such as a half time position in industry and a professorship. Provost Terman invited Carl Djerassi, Research Director of Syntex pharmaceutical firm to be a chemistry professor at Stanford as part of the strategy of building steeples of excellence in focused fields with significant intellectual and commercial potential, in this instance steroid chemistry. Djerassi brought the firms R&D operation with him to Palo Alto from Mexico City and continued as Research Director as part of his arrangement with Stanford (Djerassi, 1992). (3) Alternation or significant successive periods of time in more than one sphere, for example, Stanford Professor William Perry, after a significant business career and half-time professorship, served as Secretary of Defense and then returned to the university on a full-time basis.

❖ **Information Circulation: Innovation Networks**

Collaboration is premised on information communication that, in the IT era, increasingly occurs through networks at various levels, from local to international. Some information networks are designed to announce government policies and funding sources; cutting edge research results from universities and their implications for new technologies and industries; collaboration needs from industry. Others are also designed to support innovative regions. For example, Oresund, the cross-border region linked by a bridge between Copenhagen and Malmö is both an information communication network between Denmark and Sweden and an innovative region (Törnqvist, 2002).

❖ **Output Circulation: Reciprocity among Actors**

Reciprocity among actors and equality of contribution to innovation is another crucial factor. For example, the products of start-up firms in the nascent semiconductor industry in California initially caught the attention of the Department of Defense and NASA as a means to miniaturize equipment, energizing the civilian expansion of that industry; scientific research results by scientists such as Shockley were recognized by industry e.g. the potential of solid state physics to create better telephone switching devices; university faculty accepted funding and policies to support entrepreneurial activities from government since World War II, scaling up university research in key fields such as computer science (Braun and MacDonald, 1983).

If there is a negative imbalance in contributions; a gap might appear in innovation;

conversely a positive imbalance might stimulate other actors to increase their efforts. World War II was a key inflection point, transforming university- government relations. Prior to the war, most academic scientists were located in teaching universities, "...where they had no opportunity to do research. ... relocated by the war, they suddenly found themselves in well equipped laboratories and moved rapidly to apply their pent up energies and talents to the R&D needed for the war effort" (Johnston, and Edwards 1987: 30). Exemplified by Vannevar Bush, academics initiated policies for war-time mobilization of scientific talent and sought to attain both civilian and military objectives in the post-war (VanDemark, 2003). The confluence of these forces scaled up relatively modest university-originated regional innovation dynamics in Boston and northern California. Silicon Valley has since metamorphosed into a global innovation organizer, importing start-ups and exporting future firm founders to other regions world-wide from the Silicon Valley Diaspora.

IV. Entrepreneurial University and Various Triple Helix Models

The importance of regional clusters relative to sector supply chains increase as the productive framework shifts from autochthonous corporations to networks of start-ups, academic research groups and large corporations. Change is somewhat cyclical when start-ups grow to become multinationals and replicate traditional hierarchies even as they try to maintain their egalitarian roots. Nevertheless, as in the drug industry, biotechnology firms move up the food chain, pushing "big pharma" towards specialization in production and marketing. Separation and integration of research and production, outsourcing R&D and re-founding central labs, occurs in a continuing dynamic of firm growth and industrial development. Growing a bio-tech or IT cluster has become a virtually universal regional objective (Cooke, 1991).

Collaborations in specific projects at the micro-level constitute the base to achieve regional innovation. It must be asked: why is innovation successful in some regions and not in others, even though they have similar collaboration efforts? Part of the answer resides in Schumpeter's concept of "collective entrepreneur,"³ extended to hybrid organizations such as the New England Council in the 1920's, Joint Venture Silicon Valley in the 1990s and the recent Regional University-Industry Collaboration Committees in China. Therefore, such collaborations are not sufficient to create a macro-oriented force to lead innovation. A region also needs the organization of innovation resources to form a scale or scope economy.

4.1 Collaboration, Organization and Initiation

Promoting inter-organizational collaboration in advancement and commercialization of science and technology has become a commonplace industrial reform strategy. Government-industry-university-institute (GIUI) collaboration refers to achieving specific objectives in product and process development, at various levels, firm-firm,

³ E.g. the role of the Department of Agriculture in creating the U.S. agricultural innovation system.

university-industry, within and across national boundaries etc. The European Union has developed multi-national collaboration networks within the scientific and industrial communities as well as across the academy-industry divide (Peterson and Sharp, 1998). Thus, the European Computational Aerodynamics Research Programme (ECARP), network included almost all the EU countries and two EFTA countries, bringing together all the major European airframe manufacturers and a large number of European universities and national research institutes, focused on the computational simulation of airflows (Hughes and Christie, 1995).

The incentive for industry to collaborate with external partners is enhancement of scope. GIUI collaboration originated in Japan during the late 19th century as a means of providing industry with an R&D capability from universities at a time when industrial R&D was nascent (Kodama, 1991). It can be traced back to the formation of the industrial laboratory in the U.S., sourced at the university, with continuing consulting ties (Reich, 1985). In response to increased international competition, Congress passed the Stevenson-Wydler Act in 1980 to encourage technological collaboration between government laboratories and industry, making the interaction tri-lateral as university-industry collaborations intersected with government-industry ones (Government University Industry Research Roundtable, 1991).

To make up for deficits in academic scale; similar collaborations were emphasized in the post World War I era and thereafter in the U.K. (Howells et. al., 2006). For example, since 1990 there has been a collaboration and innovation network among Rolls-Royce and three leading UK universities to enhance Roll-Royce's ability to design components of jet engine –compressor and turbine blades (Hughes and Christie, 1995). GIUI collaboration also played an important role in China since the 1950s to foster rapid industrialization (Ji, 2006), with many successful cases.⁴

4.2 Entrepreneurial University as Driver: University-pushed Model

As knowledge increasingly becomes the basis for creating new economic activity; universities receive enhanced public attention as a generator of jobs and regional innovation (Link and Siegel, 2003; Shane, 2004). In fact, before the Bayh-Dole Act of 1980, which gave responsibility for managing economic returns from federally-funded research to the university, US universities patented or commercialized their research mainly in two ways: the Research Corporation founded by Berkeley chemist Frederick Gardner Cottrell in 1912 to administer his precipitation patents, a non-profit third party technology transfer agent; and a university-affiliated (but legally separate) research foundation to manage patents, the Wisconsin Alumni Research Foundation (WARF) established in 1924.

Another alternative is academics' initiatives. When a company declined to commercialize an invention resulting from one of Vannevar Bush's consulting projects, he founded Raytheon the 1920's, with the help of a college friend/ business person, in the emerging

⁴ See <http://www.ctiln.com.cn/cxy/index.htm>; <http://ctixm.smexm.gov.cn/2005-2/2005-221182458.htm> and so on.

radio industry. However, when an inventor is disinclined to follow up and reduce concepts to practice, inventions may languish and in effect, be ‘put on the shelf,’ just as surely as when a firm chooses not to commercialize an invention that may compete with one its products. Thus, acknowledgement of need for university involvement in intellectual property protection and commercialization took hold, initially at MIT and a few other universities that early recognized a remit and responsibility to transfer technology.

Founded in 1861, MIT is the first entrepreneurial university. William Barton Rogers, a geology professor at the University of Virginia and founder of MIT, early discerned the potential of the university as a source of regional innovation, initially to infuse the Boston region’s textile and metal working industries with new ideas. In the 1930s and 40’s, led by President Karl Compton, MIT played a significant role in the renewal of the Boston region through a strategy of forming new firms based upon university research (Etzkowitz, 2002). During the early post-war, Frederick Terman adapted this strategy to Stanford, using government funds for military research to build up a knowledge base with commercial potential that could be made into high-tech firms (Lowen, 1997). Even before Terman’s systematic efforts, firm formation had taken place from the university’s founding in the late 19th century, inspired by recognition that its engineering school could not achieve distinction unless it was part of a technological and business environment populated by technical firms: a “Science City” in contemporary terms.⁵

By and large over the first three-quarters of the 20th century American research universities were extremely reluctant to become directly involved in patenting and licensing (Sampat, 2006). Nevertheless, the Research Corporation allowed universities to outsource commercialization activities while WARF directly represented the business interest of a university. These initiatives created a development path in which universities eventually internalized technology transfer and successfully lobbied for a legal framework to legitimate and expand it as an implicit national industrial policy. Thus, the university could become an initiator of regional innovation, with government at least as a tacit supporter. The founding of the Center for Integrated Systems at Stanford to renew the semi-conductor industry, during the 1990’s Silicon Valley downturn, exemplified this approach.

Why did a university-pushed triple helix emerge in the US? Firstly, the university is relatively much stronger than industry and government in producing novel knowledge that is the basis of new technology and industries. Secondly, science policy driven by the interests expressed in *Science: the Endless Frontier* (1945) greatly helped university

⁵ See, for example, Zurich (www.sciencecity.ethzh.ch), Newcastle (www.newcastlesciencecity.com) and Stockholm efforts, propelled respectively by ETH, Newcastle University and the Karolinska Institute. O’Mara (2005) compares U.S. suburban and urban science city organizing processes, concluding that the advantage lay with Greenfield efforts in the early post-war, given easier access to land and relative lack of community opposition. Recently, the balance has shifted to cities based on perceived quality of life advantages, with opposition increasingly turned into support as universities are seen as key to economic renewal.

development during the last fifty years, resulting in a continuous spillover of research results (Davis and Diamond, 1997). Thirdly, government doesn't have to make money directly; therefore, there is less stress on its officials who try the best to help innovation than in other countries such as China. In the end, industrial innovation pays more attention to product development, rather than basic research. However, breakthroughs from basic research can result in significant innovation, forming new firms and industries. This is perhaps the most important contribution of the university to technological innovation (Zucker and Darby, 1998).

In the U.S., government's direct participation in industry is unacceptable, except for war-time emergency or peace-time equivalent such as the threatened loss of the semi-conductor industry to Japan in the 1980's. Thus, government is in the background and only sporadically takes initiatives such as founding the land grant university system in the mid 19th century, thereby generalizing a bottom up initiative instigated by scientific farmers in Connecticut, earlier in the century, a typical U.S. federal government role (Rossiter, 1975).

4.3 Entrepreneurial University as Helper: Government-pulled Model

There is a crucial difference in firm formation in different triple helix models. A spin-off is an independent economic entity irrespective of its origin. University-run enterprises (UREs) in China are part of the administrative structure of the university, i.e. with the university as owner, directly responsible for its management and liabilities, while government-run enterprises (GRE's) are part of the administrative structure of government, even when nominally owned by a state company. As a result, each actor entering the market lacked clear boundaries. To remedy this situation the government has recently mandated that universities establish offices to arrange the transition of URE's into independent firms.

Regional innovation in China is based on a "government-pulled triple helix model" in which government is the initiator and the most important actor. The model has the following characteristics: (1) government initiates and controls significant projects for social innovations as RII; (2) virtually all research universities, key research institutes and large-scale enterprises are affiliated to (central or local) government; (3) The top leader's thought gives direction to the entire country with the help of government policies and resolutions; (4) government organizes innovation agents such as high-tech development zones (including science parks and incubators), markets for technology and intellectual property and information networks; (5) entrepreneurial universities, under the leadership of the government education department, play a subsidiary role in regional development to help existing industries and consult for government policy-makers.

The model arose from China's university system following a Top-down centralist approach, with national government exercising both monitoring and command authority. Item 89 in China's Constitution prescribes that the State Department of Education is entitled, "to lead and manage the tasks in education, science ...". From 1950 to 1978, the university in China was influenced by the former Soviet Union and mainly engaged in

teaching. Research, especially military, was primarily carried on by research institutes separate from university and industry. Since the first National Conference of Science and Technology in 1978, universities started to emphasize research and engage in regional economic development.

The second National Science and Technology Conference (2006.1) called on industry to be the main actor to achieve independent innovation, with the university expected to act as an assistant. Nevertheless, the underlying dynamic operates as a sequence of government- industry-university.

Industry is predominantly influenced by government, including those firms which have been changed into private ownership. For example, the role of government was decisive, providing market protection and incentives for the adoption and use of domestic products, when indigenous Chinese firms started to compete directly with joint ventures (Mu and Lee, 2005). In Liaoning Province in the early 1980s when old style enterprises in the planned economy were poor in absorptive capacity, to say nothing of R&D and innovation; industry needed university research to renew or upgrade. Since research results with commercial potential in a few leading universities were rarely transferred to industry; government had to impel the universities to help high-tech industrial development.

Liaoning Province and Shenyang City government continuously provide lands, policies and financial aid to universities. In 1995, government granted land to build the Software Park of Northeastern University (NEU), with a size of over 500,000 square meters. The University-Enterprise Cooperation Committee of NEU, established in 2001, is constituted by the Economic and Trade Committee of Liaoning Province Government and includes representatives of the Educational Department, NEU and 35 firms. The latter comprises most relevant large-scale state enterprises in the province. In the first year of the Committee's establishment, over 500 university-industry contracts were signed; the total amount reaching ¥270 million, creating an economic interest of ¥2 billion. Before 1998, NEU was led by the former Ministry of Metallurgy and subsequently by the Ministry of Education. Since 2001, it is managed jointly by the Department of Education, Liaoning Province and Shenyang City. This decentralization greatly strengthened the university's local economic service mission.

4.4 Entrepreneurial University as Collaborator: Corporation-led Model

Corporate-led innovation has been an effective strategy for regional industrial development in Germany and South Korea. Large corporations are relied upon to play the role of RII, for example, in the German beer and car industries. Indeed, corporations have long been the main actor of technological innovation, especially in traditional resource economies.⁶ In this model, government supports leading firms as its

6. Top 500 Firms make 80% of R&D expenditures, 71% of the results of technological innovation; and 62% of technology transfer takes place among them. Policy Department of State-owned Assets Supervision and Administration Commission of State Council, SASAC, IPR Strategic Management and Law Protection

industrial policy. Thus, German companies including Benz, BMW, Siemens, Bell and BASF have developed with the help of government IPR strategy.⁷ Sweden, as well as other countries, follows this approach. Indeed, a corporate led strategy has recently been proposed for China's telecommunication industry in order to achieve indigenous innovation and sustainable development.

The role of the university in this model is as a collaborator in firm innovation, largely incremental in nature. Student projects, from BA to PhD research focus on industry problems and may be jointly supervised by firm researchers who sometimes also hold faculty status. In the corporate led model, the science park typically provides a home for R&D units of firms whose remit is to organize university co-operation projects and recruit future employees. University departments, such as Naval Architecture at Newcastle University, were often created to support specific industries. However, when an industry disappears a university may be left with an intellectual resource that no longer meets a regional need. Or, as at Chalmers University in Sweden, government supported academic research may subsidize a multi-national firm, with declining ties to the country.

A transition is underway in the "Chalmers Innovation System" from corporate-led collaboration to a start-up model (Jacob, Lundquist and Hellsmark, 2003).⁸ However, the transition is slowed by the "Professors exemption," giving academic inventors control of intellectual property. Based upon traditional special privileges for academics, such as exemption from citizens' obligation to quarter soldiers in their homes, it was included in the university law of 1916 in Sweden along with belated recognition of a university research mission (Widmalm, 2001). Recently discarded in Norway and Denmark, and currently under review in Sweden, the exemption became intertwined with academic freedom, on the one hand, and opposition to commercialization of academic research, on the other.⁹

A university role in technology transfer is emerging in many countries to foster high tech SME's, at least as an adjunct to the corporate-led model. For example, South Korea was very successful in the automobile, semiconductor, petrochemical and ship-building industries, with large corporations providing an innovation platform to develop medium and small enterprises. However, South Korea overemphasized the corporate-led model and ignored the independent development of small and medium enterprises (SMEs), resulting in its decline in the 1990s (Yang, 2006). More recent government programmes, like NURI, have emphasized university support for SME's.

in Germany Enterprises. <http://www.sasac.gov.cn/gzjg/zcfg/200607240144.htm>

⁷ Ibid.

⁸ Although venture capital to support start-up growth is increasingly available; Europe at .05 of GDP is still well behind the U.S. rate of .17, even taking into account the likelihood that a higher proportion of U.S. venture capital flows downstream to firms at later stages of development that may be bank-financed in Europe (Eichengreen 2007:404).

⁹ There were also "Professors Privileges," such as the obligation of the community to provide a certain quantity of wine, free of charge, in some university towns, well into the early modern era.

V. Conclusion: Towards a Triple Helix Society

The requisite for creating an entrepreneurial university is a “critical mass” of research with commercial potential, although limited entrepreneurial initiatives can also be created from an educational base. Lack of an entrepreneurial culture and an industrial environment are impediments to entrepreneurial transition but neither is an inherent blockage.

Internal culture and external environment are both amenable to change through initiatives encouraging entrepreneurship and regional development. Stanford exemplifies development of an entrepreneurial university at a “green-field” site while the recent history of the Pontifical Catholic University of Rio de Janeiro exemplifies cultural change through entrepreneurship and incubation projects.

A triple helix framework is emerging globally, despite uneven development, with academic culture changing at different rates in various societies. In 1913, university professors protested the Swedish Minister of Education’s statement that universities have a double purpose: “...education for careers in civil service and as ‘seat of pure scientific research’” (Widmalm, 2001: 131); more recently, leading Swedish academics published an open letter opposing the “Third Mission.”

Entrepreneurial universities also play different roles in various triple helix configurations. They jump-start regional innovation in a university-pushed environment; in a government-pulled model, they assist existing firms and industries and create new ones at the behest of government; in a corporate-led context, such universities typically collaborate with industry in product and process innovation. Triple helix development may change course over time from government-pulled to university-pushed and then corporate-led, or any other order.

Micro innovation focuses on understanding the dynamics of product and process innovation, for example, through GIUI cooperation; macro-innovation on institutional structures and relations. At the macro-level, the relative strength of available organizing and initiating capacities are the basis for designing innovation strategies that have different starting points, due to uneven development within a given triple helix. Both RIO and RII capabilities are required to upgrade collaboration to the triple helix level. The former gives a strategic direction to a project while the latter provides an initiating force. When one or the other is lacking a “knowledge space” may not be fully utilized.

We have portrayed tendencies in societal development toward triple helix that are *in nucleo*, emerging out of chrysalis into major social trends. Schumpeter observed, “the theoretical social sciences portray only tendencies within social a reality and never complete social reality (1910). We believe that triple helix practice in society will have a stronger viability.

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