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Research groups as 'quasi-firms': the invention of the entrepreneurial university

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Abstract

Academic entrepreneurship arose from internal as well as external impetuses. The entrepreneurial university is a result of the working out of an "inner logic" of academic development that previously expanded the academic enterprise from a focus on teaching to research. The internal organization of the Research University consists of a series of research groups that have firm-like qualities, especially under conditions in which research funding is awarded on a competitive basis. Thus, the Research University shares homologous qualities with a start-up firm even before it directly engages in entrepreneurial activities.

Keywords: Academic entrepreneurship; Technology transfer; Conflict of interest; Innovation

1. Introduction

This article analyzes the transition from the Research University to the entrepreneurial university. Academia has become entrepreneurial in its inner dynamic as well as through external connections made to business firms for research contracts and transfer of knowledge and technology. An embryonic entrepreneurial academic dynamic originated in the US university during the late 19th century when lack of a formal research funding system, apart from agriculture, placed a premium on individual and collective initiatives to obtain resources to support original investigation. The US entrepreneurial university emerged "bottom up" in contrast to Europe where the introduction of academic entrepreneurship is a recent "top down" phenomenon in response to the innovation gap between the US and Europe (Soete, 1999).

The academic enterprise is transformed in parallel, sometimes leading; other times lagging the transition to a knowledge-based economy. The production of scientific knowledge has become an economic as well as an epistemological enterprise even as the economy increasingly operates on a knowledge resource base (Machlup, 1962). Science has emerged as an alternative engine of economic growth to the classic triumvirate of land, labor and capital, the traditional sources of wealth. For the most part, this growth of science related technologies has remained, "... outside the framework of economic models" (Freeman and Soete, 1997, p. 3) even as the institutional spheres of science and the economy, university and industry, that were hitherto relatively separate and distinct, have become inextricably intertwined, often through governmental initiatives. Expectations that multi-national firms or so-called national champions will be central economic

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actors in the future are receding. Rather, the key economic actor is increasingly expected to be a cluster of firms emanating from or at least closely associated with a university or other knowledge producing institution.

The entrepreneurial university encompasses and extends the research university. Although some analysts view academic entrepreneurship as a deformation of the purpose of the Research University (Slaughter and Leslie, 1997), I shall argue that it was a concomitant feature of its origin and growth. Theories of the university typically fail to account for the metamorphosis of a medieval institution based on charitable and eleemosynary principles into one capable of generating a significant part of its own support. Instead, they argue for confinement to whatever has previously been accepted as academic goals such as teaching and research. Academic entrepreneurship has also expanded from an organizational growth regime into a regional economic and social development strategy. The US research university developed as a series of research groups, quasi-firms which were just a step away from becoming full-fledged firms as opportunities arose. Frederick Terman's initiatives to develop Stanford University exemplify the stage-wise institutional evolution of the academic enterprise from an ivory tower to an innovation focus.

Expansion of university mission

Teaching	Research	Entrepreneurial
Preservation and dissemination of knowledge	First academic revolution	Second academic revolution
New missions generate conflict of interest controversies	Two missions: teaching and research	Third mission: economic and social development; old missions continued

2. Main hypotheses, propositions and method

This section elucidates a set of propositions and hypotheses regarding the emergence of the university as a collective entrepreneur. It draws for data on two sets of interviews conducted at US research universities during the 1980s and 1990s, case studies of European and Latin American universities, and archival research at Stanford University.

2.1. Academic revolutions

The first academic revolution, taking off in the late 19th century, made research a university function in addition to the traditional task of teaching (Storr, 1952; Metzger, 1955; Veysey, 1965; Jencks and Reisman, 1968). A second academic revolution then transformed the university into a teaching, research and economic development enterprise. This transition initially took place with respect to industry at MIT, which was founded, in 1862, as a "land grant" university. The entrepreneurial academic model was then transferred to Stanford where it was introduced into the liberal arts university culture in the early and mid-20th century. Similar processes are underway elsewhere. An entrepreneurial academic format is currently being fashioned from a variety of historic university systems to meet the widespread need to generate new firms from knowledge resources in order to stimulate employment and productivity growth (Etzkowitz, 2002).

2.2. Research groups as 'quasi-firms'

The transformation of the teaching university introduced a democratic and entrepreneurial ethos into US academia. The attempt to institutionalize the 19th century German model of a single professor representing a discipline, surrounded by a permanent staff of assistants, introduced into Johns Hopkins and the University of Chicago in the late 19th century soon broke down. Departments with relative autonomy of professors in different grades replaced professorships with a support staff (Oleson and Voss, 1987). An assistant professor in a United States university has considerable ability to set research direction, especially if he or she can convince an outside funding source. Professors, already paid for teaching duties, assumed research responsibilities, as well. With relatively modest financial support, graduate students assist the professor, and each other, at the same time as they receive their training.

Research groups operate as firm-like entities, lacking only a direct profit motive to make them a company. In the sciences, especially, professors are expected to be team leaders and team members, with the exception of technicians, are scientists in training. As group size increases to about seven or eight members, professors who formerly were doing research are typically compelled to remove themselves from the bench to devote virtually full time to organizational tasks. Often persons in this situation describe themselves as "running a small business". To continue at a competitive level with their peers, they must maintain an organizational momentum. Once having attained this goal, it is extremely difficult to function again as an individual researcher, so every effort is made to sustain leadership of a group (Etzkowitz and Kemelgor, 1998).

2.3. The bi-evolution of the university

There is a parallel organizational transformation of the university in the shift from an individual to a group focus in all three academic missions. The shift is most obvious in the sciences where research groups have superseded professor–student dyads as the primary organizational mode. There is a similar transformation in the mission of economic and social development the university plays a broader role as "regional innovation organizer" expanding its focus from an individual patent or technology transfer event. For example, in Portugal, the University of Aveiro has taken the lead in bringing the local business community and municipalities together to formulate a regional development strategy.

There is also a transition in education, from educating individuals to shaping organizations, as well. This transition has been more difficult to discern since it typically takes place in academic contexts, such as incubators, that have been viewed as part of the "third mission" rather than as part of the educational function of the university. A special graduation ceremony at the Pontifical Catholic University of Rio de Janeiro marked the departure of firms from the university's incubator facility, "project genesis". The occasion exemplifies the educational crossover of the university's economic development mission, which follows the academic model by mandating a limited time period in the facility. The organizational/educational role of the incubator extends after graduation through a "club" linking groups of alumni firms with potential partners. Just as the university trains individual students and sends them out into the world, it is now doing the same for organizations.

2.4. Entrepreneurs: born or made?

Entrepreneurship, the ability to take the initiative to organize a new enterprise, has been presumed to be a cultural and psychological characteristic, more closely connected to and likely to occur among particular ethnic and religious groups. It has been argued, for example, that a consequence of the rise of Protestantism as a religion not tied to a central authority was its encouragement of the development of capitalism. It has also been argued that entrepreneurship arises as part of a cultural and social transition, the break with tradition and the transition to modernity. The evidence is contradictory and though the hypotheses are seeming broad; they also exclude a relevant alternative possibility, i.e. that individuals and groups can be trained in entrepreneurship through formal education and apprenticeship schemes (Jones-Evans and Klofsten, 1997).

A common premise is that entrepreneurs are created by their cultures but recent educational experiments suggest other possibilities. Project genesis at the Pontifical Catholic University of Rio de Janeiro and the Entrepreneurship Center of the University of Linkoping, Sweden, have demonstrated that people of various cultural and social backgrounds can successfully be trained as entrepreneurs. Thus, whether an individual grew up in the Swedish social welfare tradition or in a Brazilian Catholic environment, a set of courses and practical applications can be organized that will set them on the path to firm formation. Entrepreneurship is thus integrated into the academic scene irrespective of whether there is a pre-existing cultural substrate.

2.5. Collective entrepreneurship

The traditional concept of entrepreneurship typically presumes that the entrepreneur is an individual person. The notion of the heroic individual entrepreneur can serve as an ideological myth that conceals the role of academic and government initiatives in firm-formation.[1] Several persons may jointly undertake entrepreneurial roles in forming new firms and other organizations. Indeed, although some persons may not be willing or able to become entrepreneurs individually; they are able to do so collectively, as in the instance of a collaboration of Swedish computer consultants and business school graduates who formed an Internet firm.

Individuals entrepreneurs have their collective counterpart when groups and organizations take entrepreneurial initiatives. As Schumpeter pointed out, "... the entrepreneurial function need not be embodied in a physical person and in particular in a single physical person" (Schumpeter, 1949, p. 255). He identified the role of the US Department of Agriculture, in creating an agricultural innovation system from the late 19th century, as one such collective entrepreneur. Public entrepreneurship has since expanded to the Defense Department and the National Science Foundation (NSF), among other agencies. The Defense Advanced Research Project Agency's (DARPA) role in creating the Internet and computer networking industries is well known; the public venture capital role of the NSF in founding the small business innovation research program (SBIR) is less well publicized (Etzkowitz et al., 2001).

2.6. The entrepreneurial university

The entrepreneurial university has the ability to generate a focused strategic direction (Clark, 1998), both in formulating academic goals and in translating knowledge produced within the university into economic and social utility. For example, the Polytechnic Milan, a university which recently established a technology transfer office to patent and license research results reported its first noteworthy deal which has returned to the faculty member the equivalent of four years salary. This example has captured the attention of his colleagues and inspired them to interrogate their own research results for commercial potential. A university in which research results are routinely scrutinized for commercial as well as scientific potential is becoming the modal academic institution. Such an academic institution increasingly has the internal capabilities to translate research results into intellectual property and economic activity according to a predictable metric.[2]

The university is an especially propitious site for innovation due to such basic features as its high rate of flow through of human capital in the form of students who are a source of potential inventors. 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 potential seedbed for new interdisciplinary scientific fields and new industrial sectors, each cross-fertilizing the other. A dual overlapping network of academic research groups and start-up firms, cross-cut with alliances among large firms, universities and the start-ups themselves appears to be the emerging pattern of academic-business intersection in bio-technology, computer science and similar fields (Herrera, 2001).

2.7. Linear, reverse linear and interactive innovation

The linear model is still a viable route to innovation despite having received its eloge numerous

[1] Thus, an observer noted that firms in Silicon Valley with obvious academic attributes often failed to note any sign of their academic provenance or government research grants in their publicity materials. Personal communication from Mary Fenneman, Assistant Editor, Technology Access Report 29, November 2001. Another possibility is that such firms were developing university originated technology without the participation of the campus technology transfer office.

[2] For example, MITs goal is to generate a patent for each one million dollars in R&D funding (see University Profile: MITs Tech Licensing Office, Technology Access Report 3, 1990). A rate of firm-formation may also be extrapolated from an academic research funding base, given appropriate impetus. For example, the University of Chicago's ARCH venture capital unit generated one start-up per staff member per year with four staff members in 1990 (see Arch shaping up as 4th birthday approaches, Technology Access Report 3 (12)). The US Association of University Technology Managers (AUTM), which has currently 2700 individual members, estimates that 300 firms were started from university originated technology in 2000 (www.autm.net).

times. Linearity is a fruitful and indeed inevitable feature of many academic, industrial and government research projects, as well as technology transfer and firm-formation from these sources. However, the linear model, rather than operating on a presumption of automaticity, is also often complemented and enhanced by various pre and post-linear formats, including reverse linear, assisted linear, and interactive modes of innovation. Reverse linearity, starting from commercial and societal needs such as navigation aids in the early modern era, surely pre-dates forward linearity, from new scientific paradigms. Assisted linear modes are increasingly commonplace with the insertion of interface intermediation capabilities for technology transfer, incubation and venture capital within and among organizations.

The entrepreneurial university follows an interactive model of innovation that incorporates linear and reverse linear modes. Even the linear model characteristic of the Research University is enhanced as knowledge and technology transfer increasingly takes place according to an assisted linear model, moving from the research site to the place of utilization. The entrepreneurial university thus has interface capabilities such as liaison and transfer offices and incubator facilities to manage and market knowledge produced in the university at several levels, from specific pieces of protected intellectual property to technology embodied in a firm and propelled by an entrepreneur. Such interface organizations also play a reverse linear role in connecting the university to external problems, sources of knowledge and firms seeking academic resources.

3. Stanford's entrepreneurial transition

The key elements of an emergent entrepreneurial university can be seen in the transformation of Stanford University from the early 20th century. These include the organization of group research, the creation of a research base with commercial potential, the development of organizational mechanisms to move commercializable research across institutional borders and finally the integration of academic and non-academic organizational elements in a common framework. The first two elements are within the framework of the research university; the next two are part of the transition from the research to entrepreneurial academic models; the last element is a feature of the entrepreneurial university.

A series of initiatives undertaken at Stanford University in the early 20th century encouraged the transition from an academic advisor guiding a series of graduate students on an individual basis to a group research mode. Professors were expected to act more like an industrial research manager organizing a group of subordinate researchers to achieve a common end. Entrepreneurial leadership was crucial to channeling the means of academic production into a new course, "... breaking up old and creating new tradition" (Schumpeter, 1934, p. 92). Even prior to the war, Fred Terman, first as chair of electrical engineering and then as dean of engineering, provided resources to induce professors to take on larger projects and work more intensely. Faculty members who had formerly spent the summers in mountain cabins now worked with their groups, year long.

When Stanford was founded in the late 19th century, San Francisco was a shipping, trading and financial center, with few technological and industrial attributes. Shortly thereafter, however, the beginnings of an electrical industry appeared, much of it developed by Stanford graduates, who installed and maintained technology imported from the eastern United States and soon supplemented it with their own inventions and products. Firms such as Heintz and Kaufmann and Federal originated the contemporary western electronics industry (Norberg, 1976). By the 1930s, the regional electronics industry was flourishing, fed by electronics programs at Stanford. Industry and university grew in tandem. The origins of this cluster preceded Frederick Terman, whose name is synonymous with Stanford's emergence as an engine of regional economic development, and accordingly is often referred to as "the father of Silicon Valley".

How did industrial and academic development strategies converge? Northern California was originally dependent on the east for its electrical equipment and other modern technologies, and even after the engineering school at Stanford trained engineers who could configure and operate these technologies, the region still lacked its own technological industries. The founders of the Stanford Engineering School held that they could never have a leading school unless it was associated with local industry that had the capability for technological innovation, not merely replication of imported technology. Since that industry did not exist, it would have to be created. The available base on which it could be built was the engineering school itself.

Stanford took the collective entrepreneurial role in the 1930s in organizing the intellectual property generated in the university and in firms related to the university into a common project. A number of significant electronic devices, with theoretical as well as practical implications, for study of the behavior of electrons and for radar systems, were invented in the physics and electrical engineering departments just before the Second World War. Rather than the patent positions being split among competing firms and used to exclude access, the university served as a repository of economically useful knowledge that was made available to all of the firms in the region. Even Litton, a close associate of the Stanford electronics researchers from industry, assigned his patent for the generation of high frequency oscillations in multigrid tubes to Stanford.

The Stanford strategy of academic-based industrial development and industrially based academic development required the setting of strategic goals to develop research areas with conjoint theoretical and practical potential. The normal academic mode is incremental development based on unique hires conducted through individual searches within particular disciplines and departments lacking an overall framework. Terman proposed a 20-year development program, linking the physical sciences with electrical engineering.[3] A small strategically chosen number of engineering fields would be developed in coordination with relevant related fields in the physical sciences, as at MIT during the 1930s.

Terman argued that, "by determining the proper fields on which to concentrate, and then really laying it on those selected spots we can go places without needing large amounts of extra money. With 20 years, a suitable administrative basis, and reasonable backing from the President, it would be a pushover to do something really big".[4] In his view, universities typically lacked the ability to plan: "their detailed administrative operations such as new appointments, allocation of funds for new equipment, etc. are decided largely on the basis of this year's and next year's needs".[5] If Stanford could allocate resources strategically, as part of a long time program, it could move ahead of its competitors.

As funding allowed, key professors were relieved of non-research tasks, such as committee responsibilities. They were assigned full time research associates, recruited from the pool of Ph.D. or near Ph.D., to assist them in managing their research teams. The number of support staff and technicians such as mechanics, tube makers and radio technicians was also increased in order to translate ideas, "... more quickly into physical devices".[6] Following the industrial research model, researchers were required to keep laboratory notebooks on a daily basis, countersigned by colleagues. This system was productive and cost effective due not only to the low-rates of pay and the high level of results obtained, but through the flow of people through the system.

Informal arrangements at pre-war Stanford, bringing together scientists and engineers, academics and business firms, to accomplish a research goal became formally organized after the war through the establishment of research centers. The Microwave Lab began as a division of the physics department in 1945. The new center built upon Stanford's pre-war work in electronics but instead of sparsely funded projects; federal research funds supported permanent research positions. Depression era professors who could formerly be found painting their own laboratory floors were now released from extraneous administrative duties to concentrate on research.

The establishment of research centers after the war, bringing together scientists and engineers, academics and business firms to accomplish a research goal, formalized the ad hoc arrangements at pre-war Stanford. Terman initiated a three pronged financial strategy that included accessing federal funds for defense related

[3] Letter to Paul Davis, General Secretary, Stanford University, 29 December 1943. Terman Papers, Stanford University, Archives, Palo Alto, CA. Terman, on leave from Stanford, wrote from his vantage point of MIT as director of the Radar Countermeasures Lab at Harvard University, an offshoot of the war-time MIT radar project. Terman had earlier experienced MIT during the 1920s as Vannevar Bush's Ph.D. student in electrical engineering.

[4] Ibid.

[5] Ibid.

[6] Ginzton, 1953. Memo to Dean Hilgard from Director, Microwave Lab, April 9. Terman Papers, Stanford University, Archives.

research, making contracts with industry in exchange for preferred access to research results, and the development of university land. A shopping center and an industrial park, as well as research relationships with federal agencies and companies provided the financial base for Stanford's post-war ascendance. As rental and lease receipts came in from the university's real estate ventures, Terman calculated the additional number of professors that he could afford to hire.

Federally funded research centers were also expanded with industrial support. Thus, Stanford entered into an agreement with the General Electric Corporation to build an extension of the Microwave Lab. GE received first rights to the Stanford patents from the linear accelerator, the right to call upon Stanford researchers for assistance in accelerator design and office space at the university so that to its representatives could closely monitor developments. Terman was well on his way, in the early post-war era, to achieving his goal of integrating an industrial infrastructure for the university with an academic infrastructure for industry. Nevertheless, while assuming an entrepreneurial role, Stanford also continued its development as a leading research and teaching institution in the liberal arts (Geiger, 1986). Indeed, members of its faculty in the arts, sciences and medicine were among the critics of academic entrepreneurship.

4. The second academic revolution

The research universities of western Europe and the United States in the late 20th century had to come to terms with a re-ordering of institutional priorities for which there was only partial precedent in the late 19th century academic revolution that aligned research with teaching in the United States. Among the most significant changes was the attempt to integrate, in objective and by organizational tie, academic science research groups with industrial companies. Perhaps even more significant in the long run is the development of a new industrial sector based on academic research. Over the past century, at MIT, and then at other universities, academics and industrialists established a series of relationships involving consulting, research contracts, research centers and the formation of firms. The integration of such activities into the academic enterprise was often problematic and raised important issues about the nature and purpose of the university.

The integration of new academic missions has been accompanied by acute controversy at each phase. Thus, conflict of interest issues arose when research became part of the professorial role in the late 19th century. This new task also raised issues about the mission of the university. When some professors lobbied for reductions in their teaching load in order to pursue research others accused them of abandoning their calling as educators. The first academic revolution made research a legitimate function of the university in the face of objections at the time, many of which still persist, that research activities were improperly taking professors away from their traditional role as teachers.

Until quite recently most academic scientists and research universities abstained from commercializing research. This stance is changing due to pressures on the university to contribute to economic development and opportunities to gain personal wealth. In the past companies exchanged resources for trained personnel and advice across well-defined boundaries. It is now becoming more common for teachers to exploit knowledge themselves and for administrative arms of the university to assist them. The transfer of technology has been accepted as an administrative function of research universities even as publication of research was earlier accepted as a responsibility of faculty members.

In recent years, as a broad range of universities and academic scientists from several disciplines have undertaken to commercialize research, controversies have occurred and widespread concern has been expressed about conflict of interest and related ethical issues. Some critics argue that financial interests in research results may distort the judgments and actions of professors with respect to problem choice and research direction (Krimsky, 1991). Moreover, it has been held that the current direction of university–industry relations incurs deleterious long-term effects by drawing scientists away from basic research. This latter position presumes a linear model with a one way flow form basic to applied research.

On the other hand, the development of the economic implications of research findings has been found to enhance the research mission of the university, and not only by the financial contribution it can make to support new research. Vannevar Bush, an exemplary entrepreneurial academic, reported in the 1920s, how he explored the theoretical implications of ideas with his students that he brought to MIT from his consulting practice. This position presumes a reverse linear model in which theoretical elucidation also arises from confrontation with practical problems. A convergence between the two approaches in which research issues increasingly combine theoretical and practical possibilities produces a third alternative: an interactive model of innovation.

4.1. Controversies over academic entrepreneurship

Conflicts of interest disputes augur a change in the function of the university. Conflicts decline either as schools disallow the disputed conduct or find ways to integrate it into the academic system.

Once clear guidelines and organizational mechanisms to carry them out are in place are in place, conflicts of interest tend to be avoided, negotiated or adjudicated. Remaining disputes, if they are serious enough, are treated as fraud, misconduct and insider trading. Disputes over appropriate behavior are typically defined as conflicts if interest in the transition between academic formats. From this perspective, the appearance of conflicts of interest may be viewed positively as a sign of change, if indeed it is an academic revolution that is desired.

The emergence of conflicts of interest is a symptom of the changing role of an organization; they especially appear in new guises when an institutional mission is in flux. It has been asked whether an organization can, "function effectively when harboring two quite antithetical sets of norms and cultural orientations and when more or less equivalent legitimacy, and comparable organizational resources are devoted to each" (David and Foray, 1995; David, 2001). The David and Foray model is based on a presumption of separate institutional spheres with strong boundaries between them.

The entrepreneurial university exemplifies the development of overlapping institutional spheres that encourage the development of hybrid entities. Although, it may seem counterintuitive, people and organizations have the ability to reconcile seemingly contradictory ideas and practices. Thus, an organization can function effectively when two, or even three, apparently antithetical norms and orientations co-exist in the same setting. To do so they must complement and enhance as well as conflict with each other. Under these conditions, a game of legitimation takes place in which the "opposing" norms and orientations are reinterpreted, emphasizing harmony rather than disharmony, mutual reinforcement rather than detraction from each goal.

A frequent assumption made by those alarmed by recent developments is that there is a conflict between internal (university) values and external (economic) values. These critics hold that certain kinds of activity must occur in a setting that is de-coupled from the economic sphere of efficiency and profit making. Once that barrier is crossed, they fear, it becomes extremely difficult to stop the corruption of values which they believe is entailed in the accommodation of universities and the other institutions of science to the market. There is a strong analogy between some of the initial fears of critics of recombinant DNA research and the fears of these critics of entrepreneurial scientists and entrepreneurial universities. In both cases, the fear is that the breaching of a barrier, whether natural or moral, will lead to catastrophic results: the risk of catastrophe is too great to take a chance on breaching this barrier.

4.2. Separation versus integration

There are instances of conflict of interest (where not all the interests are legitimate) and cases of conflicting interests (where each interest is independently legitimate) (Margolis, 1979; Etzkowitz, 1996). The ethical requirement is not to prohibit conflicts of interest but to regulate and adjudicate conflicting legitimate interests. On this analysis, a major part of the problem in determining whether there is a conflict of interest has to do with determining whether a particular interest is legitimate or not. For example, does the faculty member's or the university's attempt to make money on a scientific discovery, or to aid off-campus groups in making money from the commercialization of the discovery, count as a legitimate interest. Here the dispute turns on the legitimacy of the role of the university in economic development.

These controversies have been about a tangle of issues, seldom clearly sorted out, often with different issues being salient in different cases. The extent to which ethical problems are involved and, if so, how to resolve them requires clarification. Central concepts such as that of conflict of interest are themselves ambiguous and uncertain in their application to university–industry relations. It is by no means clear that standard conceptualizations of conflict of interest can be straight forwardly extended to apply to universities and university faculty members.

In addition, the values (or many of them) of entrepreneurial science may already be implicit in the university and people may already be acting upon them as leaders of research groups which are quasi-firms. These entrepreneurial values are now being made explicit, in the shift from government to industrial funding. Thus, the conflict, instead of being one between internal and external values may actually be between two different sets of internal university values. The main ways in which universities have attempted to engage in relations with industry while resolving or regulating conflicts of interest over the commercialization of research can be captured in two models.

1. Separating academic and business activities.
2. Integrating research and business activities under the rubric of a broader institutional mission.

Conflict of interest restraints have traditionally been based on the presupposition of the separation of institutional spheres. The four main approaches to the control or avoidance of conflicts of interest are (1) prohibition of the activity; (2) a requirement of disclosure; (3) separation of activities; and (4) integration. An activity may be seen as too desirable to prohibit; disclosure is too weak to be effective or does not end the controversy. An attempt may then be made to maintain a clear separation of activities or, alternatively, the route of integration may be pursued.

On the separation approach, the financial interest is separated from the research interest by defining boundaries or creating structures that mediate between the two activities (differentiation and separation). This involves placing as much distance as possible between the activities involved in the advancement of knowledge and those involved in commercialization. It is believed that conflicts of interest can be controlled by drawing the different interests apart as much as possible, restoring distinctions among institutional spheres that have become blurred.

4.3. Confluence of interests

In the integration approach, research and commercialization are combined in a common framework. This involves carefully spelling out the rights and obligations of all involved parties: professors, students, the university as an institution, and industry. Adherents of this approach hold that separation constitutes an unnecessary and costly interference in the transfer of technology and that conflicts can be resolved by drawing the two spheres together under a common regulated framework. I hypothesize that the separation model will be chosen when an attempt is made to conflate new role with existing missions and that the integration model will likely be selected when the new mission is explicitly recognized. Overtime, there will be a transition from modes of separation to integration since a scientific organizational and research logic operates in tandem to make discoveries amenable to commercialization.

For example, the embodiment of research techniques in software that requires maintenance and continuous upgrading to be useful is one impetus to collective entrepreneurship. Several members of a network of molecular modelers in chemistry had founded firms to market software each had developed in their labs for specific applications. Realizing that software developed according to a common standard has greater research potential than a series of independent, specialized programs, they soon formed a research center to pursue larger research projects at a commensurate scale of funding.

Joining their scientific interests in a center also had implications for their economic interests. One molecular chemist said that, "we have even talked about starting a new company ... If there are conflicting interests then we will try to decide on the best course. But nobody's company is guaranteed a priority on anything.... You have to have some level of trust in the other person's character or otherwise these things will not work very well". In effect, the center became a "holding company" for a pool of intellectual property en-route to market.

What are the implications for academia and industry of professors, each with their own research group and matching company, forming joint academic and business ventures to conduct and commercialize their research? Despite the commitment of most academic chemists to “little science”; the practices of supporting bodies, needs for equipment and intellectual considerations suggest the likelihood that additional sectors of chemistry will follow the lead of the molecular modelers and laser specialists.

5. Technology transfer paradox

Paradoxically, academic technology transfer, while reducing uncertainty in the micro-level of interaction with individual firms, may increase uncertainty at the industry or meso-level. Introducing new technology in one firm may raise the risks and uncertainty for others, especially in an industry heretofore characterized by stable technology. Nevertheless, such an increase in competitiveness will enhance innovation and productivity for the economy as a whole. While Freeman, Schmookler (1966) and other economists of science and technology exemplify aspects of this destabilizing perspective of science and technology on the economy, they acknowledge that it has not spread widely to the rest of the profession.

The creation of an infrastructure at universities to transfer technology is significant not only for the incorporation of a marketing arm in the university, but also for its ability to enhance the marketability of academic knowledge. By taking such technologies additional steps through the development process, the economic uncertainty associated with the very earliest stages of development is reduced (Arrow, 1962). An important function of such offices is to improve the quality of information associated with these nascent technologies. Indeed, by providing a search mechanism to find the most appropriate sources for sale of knowledge, the university technology transfer office itself plays an important role for firms in reducing their uncertainty.

Although economists of various stripes emphasize the financial rather than the social element in interaction (Coleman, 1997), a reservoir of social as well as financial capital is created through the academic technology transfer process. New social relationships are created within academia as well as with industry. For example, a technology transfer unit typically maintains ties with various research groups in different fields and may play an informal role in bringing about new collaborations across disciplinary boundaries. In serving as a transport mechanism for knowledge spillover, the academic technology transfer office also functions as generator of social capital as well as an efficient search mechanism.

Under conditions of informal transfer, such as obtained in Japan during the post-war era, the opportunities for finding an appropriate home for a new technology is limited by the availability of personal ties (Kneller, 1999). The increase in the number of technology transfer offices from 25 in 1980 to more than 200 at present transforms the nature of the transfer process through the shift from informal to embedded technology transfer.[7] The collectivity of transfer offices of universities and firms create a technology market. Organizations, both private and governmental host regular meetings to bring buyers and sellers together. Information resources provided by Newsletters, Websites and technology transfer firms also enhance the dissemination of knowledge and technology.

Such formal mechanisms make it possible to cast a wider net, smoothing the exchange process and reducing the friction in transactions. Although the Bayh-Dole Act led to an increase in patenting activities by universities, academic patenting preceded the law of 1980. Indeed, it was universities who were active in technology transfer that lobbied for the passage of the law in order to obtain a stable, regulated environment for the disposition of intellectual property rights emanating from federally funded research (Etzkowitz et al., 2001).

Moreover, the effects of the Act were not limited to encouragement of this single means of dissemination. As universities paid increasing attention to the economic outcomes of research, they began to explore additional means of enhancing the economic the value of knowledge by moving it along the development process closer to the market in expectation of increasing its value. Thus, the establishment of a start-up firm and an incubator facility to support such forms became

[7] The number of European universities with technology transfer offices has increased rapidly in recent years to approximately 200 and the Association of European Science and Technology Transfer Professionals (ASTP) has been organized. ASTP operates in parallel to the US Association of University Technology Managers. Inspired by the annual AUTM Survey, ASTP has begun to survey its members (personal communication from Frank Zwetsloot, Science Alliance, 30 November 2001).

additional modes of dissemination of knowledge through commercial as well as academic channels.

If a university lacks a neighboring industrial base to partner with, it may take steps to create one. The experience of the State University of New York at Stony Brook, located at a "greenfield site in exurban Long Island in creating a biotechnology industry from the 1980s from a newly founded medical school with a concentration of molecular biology researchers is a contemporary case in point. Using funds from a state supported Center for Advanced Technology, small grants were given to researchers to explore the practical implications of their research. A technology transfer office was established to patent commercializable discoveries and an incubator project started to assist their development into firms. A key precipitating factor was the presence of a faculty member with previous success in forming a firm in the UK who provided a role model for his US colleagues.

6. Conclusion: the university and triple helix networks

Academic entrepreneurship is both endogenous and exogenous. Endogeneity and exogeneity may be defined in terms of what is developed within an institutional sphere versus what is imported into it. It is endogenous in the sense that it is an internal development within academia that emanates from the way that the research university grew up. On the other hand, university-based innovation is in part the result of external influences including military research funding. The endo/exogeneity of such university–industry–government interactions is a self-reinforcing cybernetic feedback process.[8] What are the implications of the "triple helix" for the relationship between finance and knowledge?

The first phase of entrepreneurial science refers to the internal organization of research such as the analysis of scientific research organizations as "quasi-firms" and the resource collection system and its legitimations, e.g. the "credibility cycle" (Latour and Woolgar, 1989). The second phase refers to the translation of the results of research into economic goods, i.e. "the capitalization of knowledge". As universities engage in economic activities, they shift their institutional role from purely eleemosynary to partial self-generation. The transition to less dependence upon government support occurred most wrenchingly in the UK during the 1980s, but can also be seen in the US despite being partially hidden by absolute increases of government research funding in selected areas such as health (National Science Foundation, 1999).

Sources of knowledge production, such as universities with an entrepreneurial spirit and an industrial penumbra, become more significant as an institutional sphere. In a third phase, the epistemology of economics is transformed by the economics of science, including the repeal of some "limits to growth". Products based on "intangibles" like intellectual property are not subject to all of the laws of scarcity of traditional economics. For example, the depletion of fossil fuels is expected to be mitigated by the production of hydrogen by solar photovoltaics technology derived from solid-state physics. Moreover, such intangibles increasingly influence the content of products based on physical resources even as they constitute entirely new classes of products themselves.

The basic research model of science was ascendant from the mid-19th to the mid-20th century. Before this era, discovery and utilization were more tightly integrated with the same persons often involved in both activities (Merton, 1938). Mode 2 thus came before mode 1 and was only temporarily superseded (Gibbons et al., 1994). In recent decades, these processes have collapsed into each other again, opening up opportunities for scientific entrepreneurship. For example, the first successful insertion of foreign DNA in a host microorganism in 1973 was quickly followed from 1976 by the founding of small entrepreneurial firms to make industrial applications of this new genetic technique in the production of new drugs and chemicals (Office of Technology Assessment, 1984).

A growing number of researchers and universities actively seek out the industrial potential of research. Herbert Boyer, a university professor who was a leading figure in developing gene splicing techniques was also a co-founder of Genentech, a company organized to develop pharmaceutical and other products using those same techniques. Other molecular biologists with university appointments soon participated in organizing their own companies (Zucker

[8] This development is discussed elsewhere as part of the "triple helix" model (Leydesdorff and Etzkowitz, 2001).

et al., 1998). Subsequent academic research in this field has been carried out with the knowledge that commercial implications are an imminent possibility. Whether formally and officially assigned as in Sweden, or taking place by imitation, as is typical in the US universities increasingly operate on the presumption of a "third mission" in addition to research and teaching.

The university's assumption of an entrepreneurial role is the latest step in the evolution of a medieval institution from its original purpose of conservation of knowledge. As universities become entrepreneurs, they do not give up their previous functions of teaching and disinterested research. Indeed, the leading universities, recognized as successful entrepreneurs in creating spinoff firms are also among the most successful competitors for federal research funds (Odza, 1999). Public entrepreneurship translates imperceptibly and naturally into private entrepreneurship and vice versa. Indeed, hybrid forms of public/private venture capital have been created in Israel and Brazil as part of this development of university–industry–government networks.

The academic development of the university, as in the Stanford patent pool instance or the Stony Brook incubation process, occurs in tandem with the development of a cluster of firms, assisted by public as well as private venture capital. In the US the public role in the origins of successful clusters tends to be suppressed due to ideological reasons (Eisinger, 1988). Perhaps, ironically in Europe a public role is sometimes disallowed in the mistaken belief that it is not part of the US model of firm formation that Europeans increasingly wish to emulate.

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