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Normative change in science and the birth of the Triple Helix

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Abstract

A process of normative change in academic science makes spin-off entrepreneurship compatible with the advancement of knowledge. A parallel process of normative change in industrial science produces a creative tension between organizational and scientific goals that enhances the attainment of both objectives. The creation of hybrid organizations mediating between university–industry and university–government brings these institutional spheres into closer contiguity. The emergence of triadic interactions and 'taking the role of the other' among university–industry–government in the transition from an industrial to a knowledge economy may be seen as a conscious innovative stream rather than a chance evolutionary event.

Keywords

entrepreneurial science, normative change, triple helix

Résumé

Les changements normatifs en cours dans la science académique rendent l'entreprenariat scientifique compatible avec l'avancement de la connaissance. Parallèlement, des changements normatifs dans les sciences de l'industrie génèrent une tension créative entre buts organisationnels et buts scientifiques qui permet de les atteindre plus facilement. La création d'organisations hybrides jouant le rôle de médiateurs entre université–industrie et université–gouvernement rapproche ces sphères institutionnelles. L'émergence d'interactions et une 'interchangeabilité des rôles' dans la triade université–industrie–gouvernement dans la transition d'une économie industrielle à une économie de la connaissance peut être considérée comme une tendance volontairement choisie plutôt que comme un événement entièrement dû au hasard.

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Mots-clés
changement normatif, entreprenariat scientifique, triple hélice

The university's unique status as a teaching, research and economic development enterprise, whose traditional and new roles reinforce each other, places it in a central position in the knowledge age. An entrepreneurial academic ethos that combines an interest in fundamental discovery with application is emerging as new and old academic missions persist in creative tension. Rather than being suborned to either industry or government, the university is emerging as an influential actor and equal partner in an innovation regime, the 'triple helix' of university–industry–government relations. The institutional spheres of science and the economy, which were hitherto relatively separate and distinct, have become inextricably intertwined.

Research results are routinely defined as 'intellectual property' and that property in knowledge is contested not only for its symbolic but also for its monetary value (Florida & Kenney, 1990; Hagstrom, 1965; Latour & Woolgar, 1979; Nelkin, 1984; Samuelson, 1987). A relatively small number of professors, among them some of the most prestigious of academic scientists, have set up firms, both to commercialize and to support their research (Etzkowitz, 1999, 2010; Kenney, 1986). Most universities have established technology transfer offices and some have contracted with corporations for research support in exchange for right of first refusal to license technology that is generated through these arrangements.

This article discusses effects of the growing economic salience of science on scientific norms and academic practices. An explanation of why the social norms of science have changed to support entrepreneurship, instead of entrepreneurial scientists being defined as deviant, is offered. Academic scientists increasingly take account of the economic value of research findings as the university moves into a more central institutional position in society as an equal partner with industry and government in the effort to promote technological innovation and economic development.

The birth of the Triple Helix

Although some observers call for respect for a division of labour between academia and industry (Rosenberg & Nelson, 1994), it becomes more difficult to separate a series of cognitive and entrepreneurial activities that increasingly occur along a continuum rather than in dichotomous spheres. Thus, some university-originated firms located in incubators appear as much, if not more, committed to research goals as to making money, despite the best efforts of incubator administrators to focus their attention on the latter. For example, a nano-technology firm in the Stony Brook University incubator appeared to be a basic science enterprise. Conversely, some academics are so attentive to the commercial implications of findings produced in their research groups that they can attune their research program to produce results that will be amenable to commercialization even as they maintain their pursuit of fundamental research (Gold, 1992). The apotheosis of this convergence is the conjoint firm–research group, located in the incubator facility of the Pontifical Catholic University of Rio Grande do Sul in Brazil that produces biotechnology products, papers, patents and degree students in a seamless web.

If the disjuncture between theory and invention is accepted, the appearance of entrepreneurial scientists is an anomaly (Aitken, 1976). Their research is typically at the frontiers of science and leads to theoretical and methodological advance as well as invention of devices. These activities involve sectors of the university, such as basic science departments, that heretofore in principle limited their involvement with industry. Thus, the phenomenon of academic scientists commercializing their research requires a new explanation. It must be one that goes beyond the availability of investment funds since earlier generations of scientists, such as Pasteur and the Curies, seldom took advantage of commercial opportunities (Etzkowitz, 1983). The emergence of this new role calls for the construction of a framework that can account for a pluralistic universe of science and a differentiated normative structure among scientists. Such a model should account for the emergent role of the entrepreneurial scientist in the university as well as for industrial scientists who do not necessarily experience role strain in their research setting.

Resource dependency theory suggests that entrepreneurial academic behavior can be explained by the fact that universities follow their interests and seek funds wherever they become available, government in the early post-war period and industry at present (Slaughter & Leslie, 1997). The premise of this framework is that the seeker is subordinated to the funding source. A theoretical analogue, principal–agent theory, has also been applied to understanding the so-called contract between government and academia in the early post-war (Guston, 1999). However, if entrepreneurial scientists and entrepreneurial universities are now active and equal partners in their relations with industry and government, able to negotiate on an equal basis and maintain fundamental institutional interests such as the ability to publish, then the above explanations are partial, at best.

The first phase of entrepreneurial science is the internal development of academic research groups as ‘quasi-firms’. The second phase refers to academic participation in the externalization and capitalization of knowledge in tangible products and distance learning courseware. As universities spin off for-profit entities from their research and educational activities, and fund some of their own research, they shift their institutional focus from eleemosynary to self-generation. The ability to balance among multiple sources of support, including industry, national, regional and local government and self-funding can be expected to increase the independence of the university.

During the 1980s as research results were scrutinized for commercial as well as theoretical relevance, the norm of ‘communism’ was modified to ‘limited secrecy’, with research results kept under wraps until their economic value could be protected. Given the availability now of university offices with legal staff or outside patent counsel this time lag need not be long. This shift in attitude and conduct among academic scientists with respect to the economic relevance of science contrasts with the traditional accommodation of industrial scientists. This difference may be explained by (1) the higher status of professors in the university than scientists in large corporate laboratories, (2) the transformation of the university into an economic actor, and (3) the enhanced role of the university and some of its faculty in ‘the new economy’ (Sahlman, 1999).

As the production of scientific knowledge has been transformed into an economic enterprise, the economy has also been transformed since it increasingly operates on an epistemological base (Machlup, 1962). Intellectual property is becoming as important as financial capital as the basis of future economic growth, indicated by the inadequacy of traditional models of valuing firms primarily in terms of their tangible assets. Although the contemporary research university has not become a full-fledged commercial enterprise, it has taken on some of the entrepreneurial characteristics of a 'Silicon Valley' or 'Route 128' high-technology firm even as such firms adopted some of the collegial forms and campus architecture of the university. The university's emergence as a participant in economic development has not only changed the nature of the relationship between industry and the university but also made the national university a significant regional actor (Goldhor & Lund, 1983).

Academic research groups and science-based start-ups exist along a continuum, with attention to rewards of recognition and finance. Indeed companies developed on the basis of discoveries made at universities tend to continue to publish the new findings based on their elaboration of the original discovery. Licensing, joint ventures, marketing and sales of products provide additional avenues for knowledge dissemination to broader areas of society, above and beyond the traditional means of academic dissemination. These commercial channels bring with them informal social relations that also provide pathways of dissemination (Saxenian, 1994).

Organizational change within the university, and in its relation to industry and government, is accompanied by cognitive and behavioral effects. Indeed, the conduct of academic scientists has undergone a process of normative change, a reinterpretation and revision of unwritten rules since Robert K Merton developed his classic formulation that 'the communism of the scientific ethos is incompatible with the definition of technology as "private property" in a capitalistic economy' (1973[1942]: 338). A restructuring of the relationship between science and society has taken place as science has become a significant productive force in the economy. The transformation of science, from a weak and isolated to a strong and central social institution, has affected the organizations in which science is conducted, the scientific role and the norms of science.

Norms are not invariant; they change over time, sometimes marked by controversy. Two norms of science, 'disinterestedness' and 'communism', have been at least partially displaced by an institutional imperative to translate research into economic and social use. We seek to explain why normative change, rather than definition of deviance, accompanied the emergence of entrepreneurial science. If the advancement and capitalization of knowledge can be made compatible, this transformation does not necessarily represent loss or deformation of original academic purposes (Faulkner & Senker 1995; Noble & Pfund, 1980).

To examine how the university's new and old roles (economic development, research and education) interact and conflict with each other, more than 150 in-depth interviews were conducted with academic entrepreneurs, other faculty members, and administrators. A sample of eight public and private universities, at the Carnegie I and II levels, were selected to represent universities and departments with newly emerging and long-standing connections to industry. The disciplines studied included physics, chemistry, computer science, electrical engineering and biological sciences (Mitchell, 1983). Following a pilot study of two disciplines (physics and biology) at two universities in the early 1980s, interviews were conducted in two waves, in the mid-1980s and mid-1990s.

The idea of free and open communication among scientists was espoused by most respondents, but a significant minority adhered to 'limited secrecy' and was willing to hold back findings for a period of time in order to secure patent protection. A biologist who took this position called informing interested researchers without limit, 'a 19th century idea' and felt that it was necessary to protect one's research from competitors by, 'not providing key details'. On the other hand, all physicists and most biologists accepted that university scientists could properly undertake research whose goal is set by an external agency. Most biologists believed that it was possible to combine the pursuit of basic research with the objective of gaining financial rewards from one's research while the physicists divided evenly on this question.

Deviance or normative change?

In recent years, an increasing number of scientists and research organizations have sought to simultaneously advance and capitalize knowledge, calling their full adherence to the Mertonian norms of communality and disinterestedness into question. Communism implies that property rights in science are reduced to recognition of discoveries. Full and open communication represents the enactment of this norm; secrecy its antithesis. Disinterestedness denotes the institutional relationship of scientists to society, including a set of incentives to create knowledge for collegial approbation and public use in exchange for insulation from popular sentiment (Merton, 1973[1942]). What happens when norms are flouted?

Deviance involves breaking a rule and leaving the rule intact; whereas when normative change occurs, the rule itself is transformed (Marshall, 1981; Meier, 1981). Under what conditions is normative change rather than deviance likely to occur? When behavior is inconsistent with norms, but is: (1) undertaken either by a large number of persons or by a few persons of high status; and (2) can be shown to be consistent with the values of a social system; it is unlikely to be successfully defined as deviant. Even scientific colleagues, who have no desire to become entrepreneurs themselves, seldom look upon their colleagues who do with disdain. The paucity of 'definition of deviance' can be explained by examining the position in the scientific world of many of the entrepreneurial scientists.

Entrepreneurial activities have been undertaken by leading scientists who are viewed as role models. For example, a molecular biologist at a leading research university viewed his colleagues at Harvard who have formed firms with admiration and wished to emulate them. However, the willingness of a few 'low-status' scientists to use findings for pecuniary advantage would likely have been taken as evidence of 'deviance.' If such normative infractions were negatively sanctioned they would likely have served to strengthen the old normative pattern.

For an increasing number of scientists, participating in the formation of a firm has come to be positively defined as a new badge of scientific achievement. Also, taking the path of firm formation does not necessarily mean abandoning the academy. Some, like Stanford University computer scientist, co-founder of Sun Microsystems and Netscape, Jim Clark, left the university and engaged in successive efforts at firm-formation. Others, like biologist Leroy Hood, combined firm formation with an academic career. However, the California Institute of Technology (Cal Tech) did not allow Hood to gain financially from his work in helping form Applied Biosystems in the early 1980s (Hood, 1989). Hood eventually moved to a more compatible academic environment at the University of Washington where he organized a new department in bio-informatics in collaboration with Microsoft. Cal Tech, however, has since changed its policies and has become quite successful in promoting the entrepreneurial engagement that it had previously discouraged. Johns Hopkins University, another ‘Ivory tower’ holdout until quite recently, now offers its technology transfer techniques as a role model for other institutions.

For an increasing number of scientists, especially in biotechnology and computer science, an association with a firm that they have helped start is no longer an unusual event, as it was in the late 1940s, when Carl Djerassi left an Assistant Professorship at Wayne State University in Detroit to become Research Director of Syntex, a start-up company in Mexico City. Building upon the firm’s initial success in developing a novel method to synthesize progesterone as a feedstock to the chemical industry, Djerassi and his colleagues targeted artificial contraception as a product and research objective, contributing to the literature and carrying out product development simultaneously.

A two-way synergy between academia and industry was developed that de-emphasized barriers. Syntex’s relationship with the chemistry department at the Autonomous National University of Mexico (UNAM), through joint research projects, supporting student fellowships and supplying research equipment, facilitated the department’s entry into the world scientific literature (Etzkowitz & Blum, 1995). Djerassi’s scientific achievements led to an offer of a position in Stanford University’s chemistry department. In 1960, Djerassi moved part of Syntex to Palo Alto and arranged with Stanford to continue as the firm’s research director while building an academic research program. He participated in several firm formation efforts in the ‘industrial part of his day’, combining scientific achievement with valorization of research in an academic environment that early supported this combination of dual goals (Djerassi, 1992).

Some prominent scientists who initially questioned the trend toward academic entrepreneurialism have changed their views, either as opportunities became too tempting or as they realized the importance of industrial support to the future of academic research. Thus, Joshua Lederberg, an early critic of academic involvement in firm-formation, eventually became a consultant to the Cetus Corporation (1996). Arthur Kornberg, another Nobel Laureate and self-professed traditional academic, also found himself part of the ‘golden helix’, a biotechnology firm with academic connections (1995). Robert Pollack, an academic biologist who published *Academics in Pinstripes* in the early 1980s, decrying his colleagues’ ‘corporate fling’, revised his earlier views as his university generated significant research support from licensing intellectual property. Professor Pollack came to favour the university holding equity in firms formed from academia in order to move the university closer to self-supporting status (Pollack, 1982, 1999).

Many entrepreneurial scientists believe (even as critics define the same phenomena as self-justification) that they are on the cusp of a new relationship between science and business. In many entrepreneurial scientific ventures, contrasting with the subordinate position of scientists in corporate laboratories, scientists and business persons develop strategy together, mutually shaping the course and direction of the firm and sharing ownership and control.

Normative change in academic science

Entrepreneurial scientists believe that they are acting in accord with scientific values and only a minority of their colleagues view them as deviant. Under such conditions the path is open to normative change. When behavior conflicts with existing norms, but when deeper values remain stable, new norms can be identified with these values. Thus, 'capitalization of knowledge' is found to be in accord with the advancement of knowledge and the sale of intellectual property with the service mission of the university. Proponents of change such as university administrators often exploit the conflation of norms with values by redirecting debates over controversies from values (where there is usually great resistance to change) to particular cases in which a change can be shown to be advantageous. On the other hand, disputes such as the one over the introduction of the 'Discovery Exchange' at the University of Colorado, Boulder, a new mechanism to capitalize intellectual property, can easily escalate into conflict over values. Nevertheless, at this university, and others where controversies have erupted over entrepreneurial science (for example, MIT in the early 20th century), the overall trend is to its acceptance within limiting conditions (Etzkowitz, 2010).

Reinterpretation of formerly excluded behavior often goes unnoticed when it is felt that values are not threatened, or is repressed when values are believed to be threatened but rule changers cannot psychically afford to admit to themselves their exercise in revision. Change in rules also takes place quietly when rule-makers and enforcers do not wish to admit that a change is underway for fear of loss of authority, and when those subject to the change do not protest, for reasons of self-interest or lack of interest. In the case of scientists operating under novel research conditions there may be two sets of relevant norms operating simultaneously, creating an inherently unstable situation. Sociological ambivalence between dominant and subsidiary norms that exist in a state of tension with each other operates through normative sequencing, the shift from one set of norms to another (Merton, 1973[1942]). For example, in a study of the Apollo moon scientists, Mertonian norms were found to be operative when scientists worked on well-structured problems, while counter-norms guided the study of ill-structured problems (Mitroff, 1974: 591).

Implicit in this formulation of norms and counter-norms is the existence of a mechanism for making the two sets of norms compatible with each other – the definition of a problem as structured or unstructured – thus reducing or even eliminating the conflict between normative expectations. However, if an algorithm does not exist or cannot be invented to stabilize ambivalence, it may be resolved through reinterpretation or replacement.

Sociological consonance is the result of changes in the social structure that bring heretofore opposing normative expectations into a new complementary relationship with each other or replace one set by another. Such normative change is not merely an individual phenomenon but a social process in which a significant number of persons go through the same experience and express similar new conclusions. Entrepreneurship is made compatible with the conduct of basic research through a legitimating theme that integrates the two activities into a complementary relationship. For example, scientists often say that earnings from commercializing their research will be applied to furthering their basic research interests.

Reinterpretation takes place through an experience of realizing that what had previously seemed to be in conflict really was not. Thus, an initial reaction of a molecular biologist to the possibility of doing science for financial gain as well as the production of knowledge was: ‘I never realized I had a trade’; later followed by: ‘I can do good science and make money’. This conversion experience suggests the transmutation of ambivalence – the opposition between two opposing principles, one primary, the other secondary, into consonance – reformulating apparently contradictory ideological elements into a consistent identity.

This transformation, with concomitant effect on norms, occurred initially in the industrial research laboratory and in recent decades has penetrated academia as well. Norms are stable as long as they are effective and support efficient engagement in the world. When the environment changes, norms may no longer be effective, creating a disjuncture between the workings of the organization and its environment. In the next sections I examine the institutional spheres of industry and academia and specify the trajectories through which normative change in science takes place.

Normative change in industrial science

One group of scientists, employees of corporate laboratories, has long been found to have only a partial fit with Mertonian norms. A body of research developed from the 1950s to the 1970s suggests a variety of adaptations for industrial scientists including: (1) role strain or transition to managerial norms; (2) a creative tension between organizational and scientific norms; and (3) the existence of alternative normative structures of science. Scientists in industry had been expected to conform to corporate norms but academic science had been held to be a world apart, with well-defined boundaries between science and society (Gieryn, 1983). In reviewing 50 years of discussion of the norms of science, Joseph Ben-David (1980) has argued that the different positions taken reflect the author’s views on the major political issues of their era: democracy versus fascism in the 1930s and the Vietnam War in the 1960s. The axis on which the debate turns is the desired relationship of scientists to society, whether they should be independent of or directed by political goals. Ben-David (1980) distinguished among different types of scientists in his review, holding that propositions about autonomy referred primarily to academic scientists in basic research disciplines.

Nevertheless, a central research question regarding scientists who work in non-academic settings has been the degree to which Mertonian norms conflict with organizational values (Cotgrove & Box, 1970; Glaser, 1964; Kornhauser, 1982; Marcson, 1960). Corporate norms such as maximization of profit and acceptance of hierarchical authority have been identified as incompatible with ‘communism’ and ‘universalism’. It was hypothesized that scientists who worked in industry would either exist in a state of perpetual tension or depart from the scientific role by accepting a management position. It was also suggested that a scientist could achieve a limited successful adjustment to the industrial setting by bringing to bear an independent source of normative authority, professionalism and a resistance to organizational pressures. The professional scientist accepts control over research problem choice but retains control over the choice of techniques to perform the research (Kornhauser, 1982).

In general, however, it was expected that the industrial research laboratory would redirect scientists interested in esoteric research to more practical concerns. Managers noted, however, that many scientists resisted efforts at resocialization. For such scientists the norms of science were in conflict with corporate goals (Burns & Stalker, 1961) and such conflict, with its attendant role strain, was believed to result in a loss of productivity. An extensive literature was developed in which management was advised on techniques of replacing scientists' norms with organizational goals or accommodating some of their desire for autonomy (Bush & Battery, 1950; Hill, 1963; Orth, 1959).

However, within a framework that postulated a single normative structure of science and a single normative structure in which technology could be most productively developed, there could be no satisfactory resolution of these conflicts. Of course, industrial scientists could resolve this role strain by replacing the value they accorded to autonomy with adherence to the organizational norms of their corporate employer. This role shift, while resolving the problem of role strain, is expected by other researchers to result in a loss of creativity (Pelz & Andrews, 1976). This is where the dilemma of industrial science resides: the very qualities required of the scientists in order to create innovations desired by the organization may be suppressed by it to promote smooth organizational functioning.

Yet, Pelz & Andrews (1976), in perhaps the most comprehensive study of the relationship between the productivity of scientists and research environments, found that the conditions for creativity differed somewhat from Marcson's (1960) expectations. Whereas Marcson assumed that normative congruence would produce the best environment for creativity, Pelz & Andrews found, contrary to their expectation, that satisfaction with one's job – measured by the difference between desired levels and attained levels – was only moderately related to scientific productivity. To interpret this unexpected finding, Pelz & Andrews developed the concept of 'creative tension', a state of conflict between internal desires and external pressures. A curvilinear relationship between scientists' effectiveness and creative tension was postulated; effectiveness increased as tension increased up to some optimum 'moderate' level and then decreased again if tensions were too great. Pelz & Andrews treat all scientists (regardless of research setting) as a single group, that is, norms are presumed to be invariant.

However, in their study, Cotgrove & Box (1970) provide a key finding that indicates the existence of an alternative normative structure for some industrial scientists. A significant number of industrial scientists in their sample who lacked autonomy did not experience role strain. Moreover, no significant loss of productivity was noted among this group. Thus, Cotgrove & Box postulated 'the organizational scientist' who was willing to accept direction over both ends and means, over what research should be conducted as well as how the research should be done. Thus, a scientific role that operated without cognitive dissonance was postulated for the industrial arena. However, if the thesis of a self-regulating scientific community is pared down to its base in the university, the character of contemporary academic science becomes crucial to this thesis.

Transformation of the academic–industry interface

Academic scientists have a long history of working with industry, having helped establish the early industrial research laboratories in the United States (Reich, 1985). Until quite recently most university–industry connections separated academic and commercial practices. Limits were placed on how much time an academic could devote to outside concerns – a one-fifth rule allowing one day per week became commonplace. Even as ongoing relationships, consulting arrangements were usually conducted apart from academic research, although based on the academic's expertise accumulated from campus-based research. Consulting relationships typically involved brief visits to industrial sites or conduct of discrete projects on university premises.

A consequence of this separation was that it left control of commercial opportunities for academic research in the hands of industry whereas control over the direction of research and choice of research topics was left to academic scientists. Although regular payments were made to individual consultants, the large-scale transfer of funds from industry to the university was left up to the generosity of companies. The older forms of university–industry connections involved payment for services rendered, whether it was received directly in the form of consultation fees or indirectly as endowment gifts. Thus, the traffic between university and industry was policed so those boundaries were maintained even as exchanges took place through consultation and philanthropy.

From the early years of the research university in the late 19th century, university–industry relationships were largely established at the behest of industry to serve the needs of existing companies. Engineering schools reorganized themselves to serve the research needs and supply personnel for the growing science-based electrical and chemical industries. The linkages included cooperative programs which sent students to industry for part of their training, university professors undertaking research at the request of industry and donations of money and equipment by industrial firms to support engineering education (Noble, 1977: ch. 7). University–industry relationships declined in the 1930s due to the financial stringency of the depression and became relatively less important in the post-war era with the growth in government funding of science.

The dynamics of entrepreneurial science

However, as industrial and technological competitiveness increased, for example between the US and Japan in the 1970s, the potential of the university as a source of advanced technology and future economic development moved to the forefront of global science and technology policy. A broad range of universities have taken on the tasks of economic development, at times due to external pressures, including funding constriction but also as the result of internal initiatives arising from the expansionary dynamic of scientific research. New forms of university–industry relationships involve the multiplication of resources through the university's and faculty members' participation in capital formation projects such as real-estate development in science parks and formation of firms in incubator facilities. These also include academic scientists' involvement in firms through membership of advisory boards, directorships, stockholding in exchange for consultation services, assumption of managerial responsibilities, direct involvement in the formation of firms, and so on.

Relatively few open conflicts have erupted such as the one at Harvard in 1980 when the administration proposed that the university participate financially in a firm based on the research of one of its faculty members. Although controversy over the goals of the university abated when the plan was dropped, President Bok stated at the time that he would explore other means of involving Harvard in realizing financial gain from campus-based research (Bok, 1982; Culliton, 1982). In 1988, when a joint venture involving the medical school was announced, the *New York Times* questioned whether traditional academic values were being abandoned, but there was no on-campus opposition as there had been 8 years before. During the intervening period, similar proposals had become accepted practice at other universities, as the University of Colorado, Stanford University and Columbia University accepted equity in faculty-formed firms, and Washington University, St. Louis and other schools took the role of venture capitalist.

One driving force behind normative change in academic science is industry's experience that although transfer of knowledge is, in principle, freely available through the literature, in practice, closer relationships such as consultation and inserting industrial scientists into academic research groups are necessary to translate this knowledge into a usable form. A second factor is the perceived constriction in federal funds for academic research in recent years that has made support from industry significant, even in the form of marginal amounts to supplement shortfalls in government research funds. Third, from the 1970s increased international competition with US industry led to a 'hidden industrial policy' carried out by amendments to the patent law. The Bayh–Dole Act of 1980 assigned the intellectual property rights emanating from federally funded research to universities both as a requirement for receipt of such funds and as an incentive to earn funds by transferring technology to industry. The fourth factor is the 'inner dynamic' of academic science, the necessity to raise funds to support a research group.

Processes of normative change

As academic scientists make their claims for priority concomitant with the securing of intellectual property rights to their discoveries, the conditions for increased industrial connections are being created at liberal arts research universities. These connections take place within limits that are designed to take account of the concerns of the liberal arts faculty, but these restrictions gradually erode through the development of case law in the university's oversight committee. For example, a ban on exclusive licenses Columbia University was changed to allow such licenses when companies could not otherwise be induced to participate in the transfer of technology.

Changes in university policy are institutionalized in the form of new administrative offices to carry out new tasks, or the assignment of old offices to take on new functions. Thus, at MIT in 1940s when a contract office established in the 1920s to deal with industry was reassigned to monitor military contracts, it signified the advent of an era of extensive academic– government relations as other universities followed suit (Etzkowitz, 2002). The establishment of technology transfer offices at virtually every research university during recent decades exemplifies a similar transition in academic–industry relations. As linkage mechanisms are put in place, a two-way flow overlays the traditional one-way flow of students to industry, with corporate procedures and personnel entering the university, and academic modes and professors moving to industry.

A game of legitimation

Drawing upon Huizinga's (1971) analysis of the 'playful' element in social life, it is suggested that the reworking of boundaries around institutions undergoing changes in their mission occurs through a 'game of legitimation' that takes various forms. One strategy is to conflate new purposes with old ones to show that they are in accord. For example, universities legitimize entrepreneurial activities by aligning them with accepted functions such as research and service. Thus, the University of Colorado at Boulder's science park is viewed as an expression of the research function of the university, making a contribution to that objective as well as to economic development. Bringing the R&D units of large firms into close contiguity with academic research groups to provide consulting opportunities for faculty and job opportunities for graduates are among the goals of such efforts.

The objective is to bring together complementary knowledge resources to generate new economic activity. To this end, new boundaries may be constructed that synthesize institutional and geographical elements into a new framework. Organizational innovations such as the science park and the incubator, which synthesize elements of two or more institutional spheres, exemplify hybrid organizational formats. Such institutional syntheses are analogous to the cross-border regions created among nations, such as Oresund, comprising southern Sweden and Copenhagen. Incentivized by a European Union programme to encourage joint projects and identity construction across national boundaries, Oresund is based upon a combination of geographical features, physical artefacts, such as a bridge that became a unifying symbol as well as a physical link, and a source of regional collaborations to foster high-tech industry (Tornquist, 2002).

What is new in the present situation is that many academic scientists no longer believe in the necessity of an isolated 'ivory tower' for the working out of the logic of scientific discovery (Blumenthal et al., 1986). Heretofore, in the hiatus between scientific discovery and application, industry was expected to have its scientists and engineers pursue applied research and product development. The model of separate spheres and technology transfer across strongly defined boundaries is still commonplace. However, academic scientists are often eager and willing to marry the two activities, nominally carrying out one in their academic laboratory and the other in a firm with which they maintain a close relationship.

Dichotomies such as patents vs. publication and basic vs. applied research goals, as expressions of a theory of knowledge-placed scientific advance, i.e. development of theory, in opposition to technological advance, have declined. As industrial sectors and universities move closer together, informal relationships and knowledge flows are increasingly overlaid by more intensive, formal institutional ties that arise from centres and firms. Companies locate R&D facilities near to universities with significant strength in their fields of interest. Thus, bio-medical firms locate adjacent to the University of California at San Diego and Yale University, Novartis by MIT, Microsoft next to

Cambridge and Ericcson at the Ideon Science Park, where Lund University's science and technology faculties are interspersed with company labs.

Such intensive interaction sheds new light on the question of industrial influence on faculty research direction and whether this is good, bad or irrelevant. Thus, the 'issue of investigator initiation is much more complicated because I am bringing my investigator initiated technology to their company initiated product. It is a partnership in which each partner brings his own special thing. That is the only reason they are talking. Do your thing on our stuff.' Previous conflicts and organizational modes based on an assumption of a sharp dividing line between the academic and industrial sides of a relationship are superseded as boundaries are elided and new formats invented.

Changes in academic policy and practice

University administrations have put in place policies and programs to market the research of their faculty and adjust these policies to retain the loyalty of faculty. Faculty members in fields with commercial potential such as computer science take into account the university's patent and time policies in their decision to accept or retain positions. A number of universities have established committees, representing faculty and administrators, to respond to the problems and opportunities created by entrepreneurial science. Such committees are institutional mechanisms of normative change and constitute a strategic research site to examine how different viewpoints are expressed and mediated. Their task is to translate 'ambivalence' into 'confluence'. These committees are arenas in which representatives from different social locations in the university interact under conditions where they share a common charge to produce a position.

It is often believed that modest changes in university rules will allow commercial activities to be undertaken without endangering values. However, the process of conflict resolution in committees often leads, even those most highly opposed to normative change, to allowing changes in rules to be made. Committee leaders produce rationalizations to show how old norms are not violated by new forms of behavior, thus laying the foundations for normative change. Acceptance is gained through reinterpretation of values or through concessions to interests: for example, increased financial support for the humanities from revenues accruing to the university from industry. New forms of behavior are then allowed, such as temporary withholding of research results as patents are sought, while traditional values are upheld.

Some engineering faculty at Columbia, in the early 1980's, were outraged at the attempt by the university to control their involvement with industry. They argued that it would result in the creation of a new bureaucracy that would impede communication with industry. Although no-one opposed sharing rewards with the university some were adamant about not being allowed to accept stock and make consulting arrangements at their discretion. These faculty members wished to maintain their status as independent entrepreneurs and not be superseded by the university as an entrepreneur. For example, a professor of Chemical Engineering characterized the new policy as both vague and restrictive. By giving the university control over patent rights it would create an inequity between copyright, left to the faculty and patents. He believed it would make the faculty into industrial laboratory employees and noted that: 'the university scientist, however, is unique among the members of the faculty. He raises the funds for his equipment, and from his research grants pays for the operation of his laboratories, the operation of the libraries and computers, and the stipends of his students. It is a gross exaggeration to imply that the university materially invests in the research of its faculty; the university operates its laboratories as profit centers.' Fundamentally they objected to universities getting involved in business while desiring to protect their right to do business under academic freedom. Other justifications included competitive pressures from other universities and industry, affecting Columbia's ability to attract faculty if their free access to consulting and other commercial arrangements were impeded.

The University of Chicago expressed interest in having faculty enter into relations with industry, including firm formation by faculty. Lacking actual cases at the time, the university committee discussed hypothetical instances of problems arising from industrial connections. Committee members expressed concerns over faculty allocation of time to external interests and loss of allegiance to the university. Nevertheless, the preponderant concern was to find ways to encourage such involvement in order to legitimize the university with wider society on the grounds of contributions to its economic development.[1]

Guidelines for conduct and organizational mechanisms to market patents were all oriented to encouraging faculty to become more aware of the potential economic value of their research where such interest was low. Alternatively, their purpose was to channel the translation of research into marketable products in ways acceptable to the university among faculty where interest in the economic outcomes of research was high. These responses indeed augur a shift in the direction of the research university, and its members, toward new normative patterns regarding the pecuniary content of knowledge. Whether built into organizational entities that handle the marketing of research, structured as guidelines for desired behavior or felt as enticements from the outside world, a new normative structure is emerging in the research university. They are norms in the sense that they push behavior in a clear direction with recognizable and consistent outcomes, enticing it where possible, coercing it where necessary.

As institutional spheres increasingly 'take the role of the other', universities that found firms and research-oriented firms operating as quasi-universities, holding seminars and sponsoring scientific meetings, overlap in their institutional functions. Attempts to fit new phenomena into existing categories and analyses only result in analytical confusion. For example, given the traditional separation between research and entrepreneurship, it is not surprising that 'Internet billionaires' did not invent the technology on which their fortunes are based. It is held that 'many Internet pioneers were dyed in the wool academics [who] … wouldn't or couldn't shake off the values of academia' (*The Economist*, 1999). However, many of these purported academics were actually employees of research firms such as Bolt, Beranek & Newman (BBN).

BBN was started by academic acoustical experts at MIT and provided a home for a 'third shop' of artificial intelligence researchers who interacted with their peers at MIT and Harvard (Minsky, 1987). Thus, some university professors became entrepreneurs and organizational innovators, synthesizing academic and business formats, often with government support. BBN, and its counterparts, represent one source of academic entrepreneurship, often based upon defense contracts that universities may not have wanted to assume directly (Vollmer, 1962). BBN has since become part of GTE, a telephone company, which was then acquired by Bell Atlantic. Companies such as Applied Material Devices and Motorola have also developed increasingly sophisticated training programs, taking upon themselves some of the educational functions of the university.

Nevertheless, the university is unique in its integration of teaching and research, even as it takes on some business functions. The core competency of the university has expanded from the production and distribution of human capital and knowledge to the packaging and diffusion of intellectual property, increasingly by recombining and enhancing internal and external innovations (Sampat, 1999). Indeed, corporations such as DuPont have donated intellectual property, unrelated to their core interests, to universities expecting that students and professors will be more effective than companies in taking the next steps through development. As the corporation, the university and government, as loci of scientific research, have changed their practices, so has science itself been transformed.

Not surprisingly, as its economic consequences have become more widespread, science has gained greater attention from industry and government. As the center of significant research activity in the US, the university has become the focus of policies and programs to encourage technological innovation and reindustrialization. Government has invented new cooperative mechanisms (e.g. Industry, University Research Centers (IUCRCs) and Cooperative Research and Development Agreements (CRADAs) and provided 'public venture capital' to translate academic research into economic activity, and industry problems into academic research (Etzkowitz et al., 2000; Johnston & Edwards, 1987).

Conclusion: polyvalent knowledge and the transformation of the role of the university in the knowledge age

The transformation and the interrelations of the institutional spheres of academia, industry and government increasingly shape the dynamics of innovation at the multi-national, national and regional levels (Etzkowitz, 2008; Etzkowitz & Leydesdorff, 1997). As these spheres interact more intensively, the social location of scientific research and the way research is put to use are also affected. Hybrid organizations such as cooperative research centers, strategic alliances and incubator facilities have been created at the interface of academia, industry and government to stimulate innovation. Knowledge is increasingly seen as unitary but with mutiple characteristics: theoretical and practical; publishable and patentable, at one and the same time. The transmogrification of the research university into the entrepreneurial university is premised on the universalization of the so-called 'Pasteur's Quadrant' into a unified epistemological mode of Polyvalent Knowledge (Etzkowitz and Viale, 2010).

Norms should be viewed as part of the process of social change as well as a source of stability for social order. Norms delineate how an institution works at the same time as they say how it should work. Thus, a norm is inherently value relevant since it incorporates an ethical standard as well as an empirical descriptor. Since a norm is both an 'is' and an 'ought' it has been presumed to be a relatively stable entity since, even when it is disobeyed and the 'is' does not completely hold, the 'ought' is still believed to be valid. Normative disobedience has been conceptualized as deviance and when negative sanctions are imposed it is viewed as a reinforcement of the norm in question. However, it must also be asked under what conditions is the 'ought' of a norm subject to change and how can normative change be explained.

Long-term organizational change, such as the development of academic research that has many of the characteristics of a small business – save the profit motive – helps create the conditions under which normative change takes place. Whereas financial success is a common enough goal in American society, the norms of science traditionally oriented scientists toward recognition from peers as a substitute for personal wealth. Yet the increasing financial resources required for the conduct of research inevitably led scientists to pay more attention to the tasks of fundraising, and success at these tasks increasingly became a prerequisite for the ability to achieve success in research. This experience helps explain why many academic scientists who formed firms felt that there was relatively little difference between those activities that were nominally inside and outside of the university. In both instances, they were acting as entrepreneurs.

Nevertheless, even when funds were raised to support an academic research group and not for personal profit, the research/finance linkage introduced a collectivist ethic of capital accumulation into science in contrast to the individualistic ethic of the wider society. Nevertheless, for some scientists it was but a short step to embracing the individualistic ethic as well. Many had never rejected this ethic, in any case, but merely put it aside as simply not relevant given their choice of careers. Having already secured recognition from peers for their research, once the possibility of attaining individual personal wealth through scientific achievement appeared they willingly accepted it.

Following on from the first 'academic revolution', the assumption of a research mission in the late 19th and early 20th centuries, a 'second academic revolution' is underway as universities take up the task of economic development (Jencks & Riesman, 1968). During the first academic revolution, the theoretical and specialized outlook of the graduate schools was conveyed throughout the academic institutional order (Geiger, 1999: 63; Storrs, 1953). In the course of the second academic revolution, the valorization of research is integrated with scientific discovery, returning science to its original 17th-century format prior to the appearance of an ideology of basic research in the mid-19th century (Kevles, 1978; Merton, 1970[1938]). Just as a research ethos was universalized throughout the academic sphere, so is a concern with maximizing the economic uses of research that was formerly the province of a specialized academic sector – the land grant schools (Veysey, 1965).

Nevertheless, industrial research funding and receipts from licensing of intellectual property rights are small in absolute terms in comparison to government funding sources that have become traditional, with their controversial origins forgotten by succeeding academic generations (Genuth, 1987). Nevertheless, a secular trend can be projected of an academic system, closely involved with industry as well as government. During the 1980s industry funding of academic research rose from about 4 percent to 7 percent and, by the end of the 1990s, to about 10 percent. Much of this increase was concentrated in a few fields with strongly perceived industrial relevance, such as biotechnology and civil engineering. University research centers closely tied to industry increased nearly two-and-half times during the 1980s. The number of patents awarded to US universities tripled between 1984 and 1994 (Zusman, 1999). While still small in scale, if not in scope, a new academic and societal model is emerging from its chrysalis.

Normative change in science and the birth of a triple helix is part of a broader transition from an industrial to a knowledge society. The creation of venues, especially at the regional level, where representatives of these institutional spheres interact, both publicly and privately, and plan new initiatives for economic and social renewal, heightens the importance of networks and relations among institutional spheres. The university, a secondary institution in industrial society as a provider of trained persons and research findings, moves into a more central role in the transition to a knowledge society as a source of new technologies and new industries.

Government and industry, the major institutions of industrial society, thus become part of a triad of university–industry–government in a knowledge-based regime. The efflorescence of triadic interactions and 'taking the role of the other' among university–industry–government is a conscious innovative stream rather than a chance evolutionary event.

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Notes

Unless otherwise noted, quotations are drawn from the research studies acknowledged above.

1 The University of Chicago had a significant entrepreneurial success through its ARCH technology transfer and venture capital arm, organized in collaboration with Argonne National Laboratory (see Candell & Jaffee, 1999) and subsequently established an on-campus technology transfer office (Etzkowitz, 2009).

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