

Introduction

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A new common form of academic institution is emerging in the late twentieth century. From its medieval origin as a corporation of scholars or students, the university is evolving into the contemporary entrepreneurial university. Specialized institutions such as the Princeton Institute of Advanced Study have not proven to be as effective producers of research as universities with students. Research universities, combining research with teaching, have long since displaced teaching colleges as the academic norm. Recently, a broader class of research universities has taken on economic development as an institutional mission. In the United States, technology transfer tasks had largely been confined to the "land grant" schools, a special class of universities created in the mid-nineteenth century to foster scientific agriculture. The Massachusetts Institute of Technology, for decades virtually a unique anomaly in United States higher education, originated as part of a contemporaneous movement to infuse industry with science.

An academic revolution is a change in the purpose or mission of the university. As medieval institutions, going back more than one thousand years to their establishment in Paris and Bologna, universities appear to change at a glacial pace. An academic revolution would appear to be a contradiction in terms. Originally conceived as institutions of cultural conservation, preservation, and transmission, they existed solely for that purpose for many centuries. As an institution of medieval origins for the conservation, renewal, and transmission of knowledge, the university, has retained its original characteristics even as it has expanded its purview to encompass new missions. The continuity of the university resides in its history of development: each new task has evolved out of an effort to meet a previous goal.

The first academic revolution was the transformation of universities from institutions of cultural preservation to institutions for the creation of new knowledge. Putting that knowledge into use followed soon after. The second revolution, the translation of research into products and into new enterprises,

started almost at the same time as the first; the former almost immediately engendering the latter. Until recently, many leading research universities eschewed an active role in the transfer of knowledge. This stance has changed due to external pressures arising from constriction in government funding for academic research accompanied by growing awareness of opportunities for the practical uses of academic knowledge.

Knowledge as Capital

The transformation of science into economic goods is not new. Certainly most technological knowledge derives from industrial practice. Indeed, these innovations have stimulated scientific progress as well, in fields such thermodynamics and information theory. There have also been significant instances of the transformation of scientific ideas into industrial use since the advent of the Industrial Revolution, classic examples being the chemical and electrical industries. What is new is the intensification of this process, including the shortening of the time span between discovery and utilization, and increased reliance of industry on knowledge originated in academic institutions. During the past two decades the capitalization of knowledge, formerly confined to a few disciplines and applied sciences and to a relatively few institutions (such as MIT and Stanford in the United States, Salford in the United Kingdom, and Campinas in Brazil), has been generalized to a much broader range of academic institutions.

This process is increasingly international, taking place not only in the United States but around the world in both developed and underdeveloped countries. It is a feature of capitalist-free market, mixed economies and socialist and post-socialist economic systems, North-South, East-West; nations and regions, each for their own reasons and, at times, at the instance of international agencies such as the World Bank and the United Nations International Development Organization (UNIDO) have focused on the the intersection of academia and industry as a potential fulcrum of future economic development (Ogbimi 1990).

Creating science-based industries from academic research is a common theme of industrial policy, whether made explicit as in France and Mexico or left implicit as in the United States. Such policies are constructed on the basis of a new relationship between universities and industry, involving transfer of technology as well as access to trained personnel. The perception that university-based science and technology is of use to industry has led to changes in the rules governing how universities and companies interact with each other, shifting the relationship from an eleemosynary to a business basis. Similarly,

the decline of traditional industries and the struggle to revive or replace them has politicized scientific and technological spheres, heretofore viewed as non-economic, self-organized, and best left unregulated. It has resulted in a change in the mission of the research university, giving it an economic development as well as an educational and training responsibility.

Leading liberal arts universities, when they became involved in practical affairs during the postwar era, oriented themselves to the national political arena. They typically eschewed any interest in the economy of their region until the recent era of uncertainty in research funding. University policies to capture the economic outcomes of campus-based research and campus involvement in efforts to aid the local economy have raised explicit discussion and caused controversy over the norms of science and the university. Of course, there was always an economic side to the university, since it received tuition payments, research grants, and gifts. But until recently, even when university endowments were invested, neither liberal arts professors nor administrators directly participated in the capitalization of knowledge.

Now, as the research university moves to assume a third function—economic development—there is concern that attention to economic issues will negatively affect the conduct of research. Transfer of knowledge to industry was theoretically freely available through the literature. But in practice industry needed relationships with academic scientists to translate this knowledge into a usable form. This is one of the driving forces behind normative change in academic science, although the relationships were initially formulated to insulate academic scientists from industry pressures. Academic scientists have a long history of working with industry, having helped establish the early industrial research laboratories in many countries.

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. In the United States, the “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 the conduct of discrete projects on university premises. A consequence of this separation was that it left control of commercial opportunities of 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. Thus, the traffic between university and industry was policed so that boundaries were maintained even as

exchanges took place through consultation and philanthropy.

Even the advent of federal funding appeared to support the existing social structure of academic science. Since research funds were largely controlled by committees of academic peers the postwar federal funding of science tended to support traditional academic models of autonomy. Nevertheless, the internal working of these forms was modified through scientists' interaction with granting agencies and attending to their priorities as part of the process of securing research funds. In addition to writing articles when they felt ready to present knowledge to peers, scientists had to at least project a future "product" from their research such as a cure for a disease or an economically relevant technology. This was the implicit contract between scientists and society set forth in Vannevar Bush's government report *Science: The Endless Frontier*, the charter document for the National Science Foundation. Since support for research was virtually guaranteed by the government during the early postwar era, researchers could afford to be relatively unconcerned with the practical outcomes of their research. Now the bill has become due and those earlier promises, whether they were meant to be taken literally or not, have become a contributing factor to changing the purpose of the university.

Even as issues of the balance between research and teaching emanating from the first academic revolution remain in dispute, the question of the appropriate relationship between academic research and the disposition of the economic value from that research was not settled at that time. Should the economic value of research be captured, enhanced, and marketed by the university, or are these tasks best left to other institutions to undertake? Different countries, and separate classes of universities in the same country, have taken one or the other course. As each new mission overlays older ones, there are disputes over whether the new task enriches or detracts from its predecessors. A natural experiment in the social organization of the appropriation of economic value from research, and on the relationship between research and teaching, has been underway for more than a century. Various formats have arisen in different countries either to integrate one or more of the functions of teaching, research, and economic development in single settings, as is common in the United States, or to divide them among separate settings, more typical of Europe.

A series of disputes, and their resolution, at MIT in the early twentieth century have provided U.S. universities with models for the conduct of relations with industry in succeeding years. The "one-fifth rule" allowing consultation one day per week, the decision to patent and market academic research, initially through an intermediary organization and later by the university itself, and the role of the university in regional economic development, capitalizing firms from academic research, originated at MIT. During the past two

decades these formats for academic-industrial relations, heretofore relegated to a special academic sector, have spread throughout the U.S. academic system (Etzkowitz 1994).

Academic-industrial relations have become a central theme of economic renewal not only through government policy initiatives, but also from changes within universities and companies associated with the emergence of an innovation system based on lateral ties. Conflicts between universities and companies have arisen in the course of these developments from negotiators' divergent conceptions of the appropriate role of their counterpart's organization, as well as from disagreements over contract terms. Researchers, as well as practitioners, base their analyses on different assumptions about institutional mission and often talk past each other, as well.

Alternative Models of Academic-Industrial Relations: Knowledge Flows and the Triple Helix

Two contrasting models of academic-industrial relations have been posed: "knowledge flows," based upon separation, and the "triple helix," denoting integration of institutional spheres. Explicating these models, and the assumptions on which they are based, could clarify various aspects of university-industry relations, including conflict of interest and commitment and the appropriate role of government at the academic-industrial interface. The triple helix model is based on ties among overlapping institutions, whereas the knowledge flows schema is premised upon separate academic, industrial, and governmental spheres. Real differences exist between universities as well as faculty members in devising strategies for industrial relations. To clarify controversial issues it is often helpful to sharpen them in "ideal typical" theoretical dichotomies even though reality is, of course, more complex and, as we shall see, occurs along a continuum (Weber 1922).

The definition offered here of knowledge flows is a synthesis derived from academic analyses (Feller 1986; Faulkner and Senker 1995) and statements by practitioners such as the Director of R&D at Philips (Bulthuis 1996). According to this model, universities produce knowledge, transmit it through publication, and ideally do not sell it. Linkages between the spheres and flows of knowledge across them are shaped, both organizationally and ideologically. For example, many academic departments value only publications for promotion and their members attend to the practical implications of research incidentally. Traditional academic ideology allows a narrow, yet highly effective, one-way channel from basic research to industrial innovation, the so-called linear model.

This hydraulic system of knowledge flows consists of reservoirs, dams, locks, and flowgates through which knowledge, codified and tacit, is

exchanged for resources across clearly delimited boundaries. Transfer of technology, as opposed to knowledge, is conducted solely through intermediaries, such as a technology transfer office collecting invention disclosures and obtaining patents for sale to industry. However, such pecuniary efforts are viewed as counterproductive to the academic mission and cost ineffective, to boot. In this view, academia's special research mission lies at the basic end of the spectrum and governmental efforts to divert universities from this course are misguided.

The knowledge flows model specifies institutional missions narrowly: universities are assigned functions of education and research; industry, production; government, regulation. In its traditional role, the university is the producer of trained persons to send to industry according to IRDAC in the European Union and the Government, University, Industry Research Roundtable in the United States. The academic side of this perspective is a zero-sum game: if universities and their faculties become involved in development activities or firm-formation ventures, their basic research effort will inevitably decline. In the industrial view, the primary role of firms in innovation is to produce incremental improvements derived from experience with production and closely associated R&D. On the other hand, universities as a site of basic research are expected to be a source of discontinuous innovation.

The knowledge flows thesis is based on the assumption of a linear model, with a one-way flow from basic research to innovation. Alternatively, a spiral model has been suggested with a reverse flow from industry to academia, as well. Such an iterative effect, in which industrial innovation opens up new basic research questions, suggests that academic involvement in industrial innovation enhances the performance of basic research. Indeed, survey data showing that academics with industrial connections publish more than their peers lacking same indirectly supports this thesis (Blumenthal et al. 1986).

Knowledge flows are a key element of university-industry relations; some suggest it should be the only dimension! Yet as more intensive relations of increasing complexity emerge, often involving government, a new model, the triple helix, is required as an overlay upon knowledge flows (Etzkowitz and Leydesdorff 1997). In addition to linkages among institutional spheres, each sphere takes the role of the other. Thus, universities assume entrepreneurial tasks such as marketing knowledge and creating companies even as firms take on an academic dimension, sharing knowledge among each other and training employees at ever-higher skill levels.

As we suggested above, dichotomous models of academic-industrial relations seldom precisely reflect reality. Various parts of the same university can be found to operate according to different models. Indeed, members of the same department or research unit may operating according to contrasting conceptions

of the proper relationship between university and industry. Such differences often result in conflict of interest and commitment controversies when viewpoints collide in the interpretation of particular cases in the same academic institution. In addition, linkage varies as one moves from one technology sector to another. The linear model may apply most clearly to the pharmaceutical sector, whereas a "chain" and "spiral" model may apply to ceramics, while neither model seems to clearly encompass the data on parallel computing.

The Role of the University in Industrial Innovation

Contemporary innovation is a precarious business. This is not simply because of transitional difficulties associated with the creation of a new innovation cycle. Rather, innovation, in the context of late modernity, is intrinsically more difficult to control, to be sure of, and to anticipate than in the past. And this condition is likely to prevail. In the fields of science and technology, the more powerful our knowledge the more difficult it is to control or decide what direction it is to take, even more to agree upon the most appropriate criteria to evaluate and regulate it.

This pressure to differentiate and specialize is met by as strong a desire to reintegrate our understanding according to new intellectual and professional boundaries. So one of the dynamics of society today is that boundaries are continually being eroded and renegotiated. New knowledge grows at such a pace that skills and the boundaries they define rapidly outdate, while there is a simultaneous tendency toward what has been called innovation overload. As a result, there is a continual pressure to audit and evaluate our knowledge base, to filter critical from non-critical technologies (Branscomb 1993), and to protect at institutional and national levels the intellectual and material capital on which future innovation depends.

As the intellectual boundaries within the knowledge base—between the sciences, for example—become more permeable, traditional professional and sectoral divisions (within industry) also begin to break down. A new division of labor has emerged, a more complex system of users and producers of knowledge and information, which has enabled the growth of new types of trans- or inter-organizational structures. Indeed, networking, cross-institutional linkage, informal and formal collaboration are all not merely possible but necessary if public and private agencies and individuals are to cope with the increasing differentiation and complexity of today's innovation systems. Companies, for example, coping with the demands of the globalization of production have sought to increase their involvement in strategic partnering at national and international levels.

This is leading to a growth in not only vertical but also, more significantly, of horizontal ties between firms. Large firms' innovative capacities will depend on access to both basic science and a key set of core technologies. Many science-based firms have sought to restructure their activities around a key generic technology, such as the U.S. corporation Monsanto, which uses biotechnology across a wide range of its research and development (R&D) areas in agricultural, chemical, and pharmaceutical innovation. In short, new organizational opportunities and demands exist for all organizations closely tied to the knowledge base.

This book explores how these processes are reshaping the specific relationships between academia, industry, and government, the principal players in the innovation system. In particular, universities and firms have become more alike in that both are involved in translating knowledge into marketable products, even though they still retain their distinctive missions for education and research on the one hand, and production and marketing on the other. Moreover, the circumstances of the innovation system make the two sectors more dependent on each other. Companies seek relevant knowledge wherever it is available: from other firms, government research laboratories, and universities. Technology transfer personnel are commonplace in larger firms and regularly attend meetings where universities, small firms, and government laboratories present their intellectual property to potential customers.

Universities have experienced a similar transformation through the development of offices to seek out and market useful knowledge developed on campus. As a result of financial pressures and incentives, universities have broadened their activities from education and research for its own sake to meeting specific research needs of industry. Although it is still a relatively small proportion of their income, universities are beginning to earn substantial sums from their technology transfer activities (Etzkowitz and Stevens, this volume).

As the third player in the innovation system, government—at regional, national and international levels—has been instrumental in encouraging universities to undertake responsibilities for economic development. Most notably, the university as a producer of knowledge on which new firms can be based and as an administrative structure to provide a home for the early stages of firm formation has become a key element in a high-tech regional economic development strategy. Working the interface of academic-industrial relations has become a watchword among institutional sectors and across national boundaries. These relations, formerly the special interests of a small coterie of academic institutions and firms, have formed the basis of a general model of how to create knowledge and wealth simultaneously in the late twentieth century.

The book's title, *Capitalizing Knowledge*, is intended to convey a process that has both economic and symbolic meaning. That is, it refers to the translation of knowledge into commercial property in the literal sense of capitalizing on one's intellectual (scientific) assets; more generally, it refers to the way in which society at large draws on, uses, and exploits its universities, government-funded research labs, and so on to build the innovative capacity of the future. These two are related of course: university spinoff firms, for example, may commercialize a technique developed during basic research in a particular area, which provides short term revenue. But the income-generating technique is also likely to feed back on and enhance further basic research, contributing to the wider knowledge base of that discipline.

Getting the right balance between these private and public functions of knowledge is often more difficult than the preceding comment suggests. Indeed, there are many who have written about a growth in conflict of interest between the public and private interests of contemporary research. Harvey Brooks (1993), for example, has argued that the level of privatization of university research that has already taken place in the last decade should not be encouraged to grow (225). Others express concern that the moves toward further commercialization of science will erode the basic science base, that the focus on patenting and exploitation of university research is misplaced and unlikely to yield net returns (Feller, *ibid.*), while many point to the complications a more commercial university orientation can generate for the academic experience of students (Louis and Anderson, this volume).

On the other hand, there are also many advocates of further ties between the academic and industrial sectors. These include government, as is evident in the British government's recent White Paper on science and technology (*Realising Our Potential* [HMSO 1993]) and the U.S. administration's move toward a more formal industrial policy that pushes national research laboratories toward a more extensive technology transfer role. Industrialists, too, often argue for stronger ties, summarized, perhaps, in the recent statement by the president of R&D at Hoffmann-La Roche that university departments and institutes should gear their research projects more closely to society's needs (Drews 1993). Evidence (Mansfield 1991) indicates that some sectors are notably reliant on academic research for the development of new products and processes, especially information technology and the medical instruments, drugs, and metal industries.

These very contrasting positions can only be evaluated by a close examination of the changing relationship between academia and industry. This is precisely what this book sets out to do. There are a number of key questions, which the different contributions to this volume seek to address. These include:

- What changes are taking place in the relationship between academia and industry, and how is this to be related to the wider changes in the innovation system?
- Are there limits to the capitalization of knowledge, and have these been reached?
- Are there any trends in the direction and form of academic-industrial relations, and how do these vary as you move from advanced industrial states to developing, middle-income, and post-socialist economies?
- What are the critical issues that we need to address now and in the future both about conflict or interest questions (and their ethical dimensions) and the development of a stronger research activity in the field of academic-industry relations?

Only by answering these can we begin to deconstruct the polarized positions on the relations between academia and industry sketched out above.

Stages and Forms of Knowledge Capitalization

Today, most industrialized states in the world strive to secure the most effective exploitation of their respective knowledge bases. These bases are reproduced and developed through the activities of both public and private research scientists and engineers, a battery of legally secured intellectual property rights, and a broad range of science and technology policies geared toward market-led investment in the economy. Much of this is taken for granted, the cultural and economic infrastructure on which it depends only apparent perhaps when efforts are made at constructing similar institutions in post-socialist Central European states. In other words, the capacity to initiate new forms of academic-industrial relations depends upon a wider infrastructural capacity to capitalize knowledge.

The processes that drive this capitalization are many and varied, and include: reductions in state funding for public sector science that force establishments to look elsewhere to sustain their research and training programs; a devolved responsibility—and so opportunity—to universities and the like to commercialize their activities; pressure on firms to both access the wider innovation environment and buy into it when and where appropriate; and finally, what Elzinga (1985, 1988) has called an epistemic drift toward measuring the utility of science in terms of criteria that are steered by market considerations. All these factors have brought changes to the institutional character of university and related science, which can be said to have occurred primarily—though not exclusively—over the past fifty years in western Europe and the United States.

Thus, at the level of the university the process of capitalization has occurred in three stages: first, the securing of intellectual property; secondly, the restructuring of research groups to generate a large intellectual property base; and thirdly, the establishing of corporate vehicles—such as spinoff firms—within universities to maximize the return on intellectual property. These three, broadly, follow on from each other historically, the earlier stages not being displaced by the later but developing in tandem with them as new demands and opportunities arise. The actual speed and timing of the three have varied between different countries, though the more recent tendency to monitor and match science policy changes has meant that there has been a growing convergence of both the timing and content of initiatives. So, for example, in 1985 the U.K. government invited universities to take up responsibility for patenting their intellectual property rights, a move that was a direct response to similar changes introduced in the United States in 1980.

The securing of intellectual property generated by universities began to be taken seriously in the early 1900s, although patent laws had existed for almost 200 years by then. One of the earlier examples of this was Banting and Best's discovery of insulin, the rights to which they assigned to the University of Toronto where they were faculty members. Wisconsin's Alumni Foundation was one of the more successful agencies securing rights to agro-biological research and through licensing patented work brought a growing level of income to the university to improve its science base. The U.S.-based Research Corporation, again established in the early 1900s, was another important private sector agency that licensed-in intellectual property from universities in return for royalty payments.

In the United Kingdom, the equivalent agency was the (publicly funded) National Research Development Corporation, established in 1950, subsequently subsumed within the British Technology Group, now privatized, but still serving to help identify and commercialize university invention. The role of these national agencies, while of continuing importance, has been weakened by the parallel emergence of technology transfer organizations within universities themselves which patent, license, and market intellectual property generated on campus. One of the most ambitious of these is the University of California's for-profit Technology Development Corporation, which was initiated in 1993 with a target income of \$100 million through the licensing of prototype developments to industry.

The second stage of organizing research activities to create a greater volume of exploitable knowledge can be traced back to the development of group research in the university. While the individual scholar pursuing his or her research is still the predominant model in the arts and humanities, in the physical and biological sciences and to a considerable extent in the social sciences the increases in productivity that can be obtained through the division of labor

has led to more organized modes of research. In the United States, organized research units date from the establishment of Agricultural Experiment Stations during the Jacksonian era, and in France and the United Kingdom, it was also agriculture but geology too (in relation to the search for minerals) which saw the development of state-funded research groups. Many other areas followed quickly in response to the economic, military, and health demands of the state through the first half of this century.

More significant changes have followed during the postwar era with the advent of research teams heavily reliant on their professor—the academic entrepreneur—who must act as fund raiser, personnel manager, publicity agent, and research director. These groups operate today as “quasi-firms” within universities, lacking only a direct profit motive to make them a business. Larger groups will be required (by contract) to provide their own corporate development plans, may operate on full economic cost accounting, secure their own patenting rights, and engender a range of technological spinoffs from their continuing basic or strategic research. The more successful they become the more likely they will find that a smaller proportion of their income comes from the core funding they receive from the university or government research budget: as such, they will be under further pressure to commercialize their research results to secure additional income.

This leads to the third stage in the capitalization process, the establishing of corporate vehicles—such as spinoff firms—to generate revenue. Spinoff firms can be of three types (Stankiewicz, this volume): contract and consulting firms, technology asset firms, and product-oriented firms. The first tend to remain relatively small, service-oriented companies, the second sell developed technologies to the market, while the third provide hard product lines (such as purified enzyme production, or specialized equipment) to larger corporations. The capacity to grow varies considerably across these different types of spinoff, related to technology sector, level of financing, relation to the wider marketplace, and organizational infrastructure they require. They tend to locate in close proximity to their parent university, typically on a neighboring science park: Stanford, for example, has spawned more than ninety high-tech firms employing more than 25,000 people and returning an annual \$14 million in licensing income.

The terms on which universities capitalize their intellectual property through spinoff firms also varies. Typically, universities prefer to share in the proceeds from spinoffs via royalties rather than equity, although the latter method is increasing. Indeed, it has recently been argued that equity rather than the apparently safer (though lower value) return of royalty payments can in fact provide higher and, over the long term, more secure income for universities (Lefkoff and Gander 1993).

The three stages of capitalization can often be found to have come together in major universities that have developed large industrial liaison divisions for handling the commercialization of university intellectual property rights, through whom large joint collaborations have been established (perhaps with a pharmaceutical firm, for example) from which discrete spinoff firms are created to cash in on some specific technology or expertise which the collaboration has brought to fruition. Government research establishments replicate this process, increasingly so in the United Kingdom, where research agencies are required to market test their expertise, or where Research Council institutes have established joint firms with the private sector to market their products, such as the Medical Research Council's equity share in the firm Therexsys, initially funded by venture capital to develop new gene therapy techniques. The Medical Research Council also holds 106 licensing agreements (*Scrip* 1993).

In addition, there has been growing pressure on publicly funded research organizations, such as TNO in the Netherlands and the CNRS in France, to relate their basic and strategic research activities to the commercial market. In the United States, government has encouraged national research laboratories to establish cooperative research and development agreements (CRADAs) with industry (following legislation in 1989), through which more than 500 agreements had been contracted by 1993.

Conflicts over the Capitalization of Knowledge

Not surprisingly, these changes imply a shift in the orientation of the academic and public research culture, from being devoted exclusively to the research and training interests of professional staff toward being open to more entrepreneurial activity. The latter raises potential conflict of interest questions and normative conflict between the expectations and standards of academia and those of private enterprise. Conflict of interest may be said to exist when an individual is diverted from a group's broader goal to an individual or private goal. The issue arises most clearly when an individual within organizational responsibilities seeks to gain a personal private profit through her or his position. Thus, if the pursuit of disinterested knowledge is raised as the banner of the research university then the receipt of private profit for research pursued is *ipso facto* a conflict of interest.

In academia, of course, this issue has arisen most strongly when faculty members have organized firms based on their research or have equity in commercial developments sponsored by corporations funding their work. Some of the more notable examples of both forms of cross-sectoral interest have been

in the biotechnology field, as new firms were spawned during the 1980s to commercialize the new techniques and processes developed in the area. After something of a lull here, the technologies and information needs of the Human Genome Project have led to a recent rash in academic-based firm formation, or firms whose principal executives were key players in the genetics research community.

Academics who embark on commercial activities can respond to this in at least two ways. On the one hand, it can be seen as an activity that must be kept separate from their more traditional roles and responsibilities, ensuring in particular that the research and development agendas of the two are discrete. On the other hand, such activity can be redefined as part of the legitimate role of academics and universities who define their tasks as contributing to innovation and economic growth as well as to the pursuit of knowledge. Since government science and technology policies appear to support this second view it is not surprising to find it in the ascendancy. Yet the more university scientists are involved in exploiting intellectual property the more their need to restrict the dissemination of detailed information about their work.

It is, of course, nothing new to find scientists reluctant to publish their work fully and freely because of professional competition with others; yet because of the new commercial pressures, this can be increased to a point where collaboration, dissemination (even in its more guarded mode), and proper peer review become compromised (Packer and Webster 1996). It is important therefore to determine whether the normative and ethical codes that have been traditional to academia have shadowed the institutional shifts implied by the three stages of capitalization outlined above. It would not be surprising to find that these shifts toward more commercial activities in universities have affected the relationships between faculty and students and the definition of academic work itself.

Transitions are seldom smooth as institutional spheres are transformed and boundaries among them redrawn. Survivals from the past, including feudal structures from the medieval period, have persisted and been extended to cover new relationships between faculty members and graduate students in areas such as the conduct of research. For example, in the assignment of authorship, quite often the intellectual producers are graduate students but professors automatically become co-authors in exchange for providing the infrastructure to produce the research for the article. This was an acceptable system under conditions when students were assured of the reward of the doctorate and movement into their own professorship. However, when such jobs are not as available the system starts to break down. Graduate students have organized unions at Yale and other universities, demanding better pay and working conditions during their "indenture" period. In some instances, they

have gone on strike, withdrawing their teaching services, in an attempt to achieve status as a recognized group with negotiating rights.

The relations among faculty, students, and administration are subject to further strain when pecuniary as well as reputational rights are subsumed within a medieval structure. In recent years, the concept of graduate students as inventors has taken hold as academic administrators have been made aware that intellectual property as well as papers are produced in the course of research. Universities have asserted ownership rights to inventions on the grounds that students are "officers" of the university by virtue of their appointment to research assistantships with putatively the same status as faculty. Faculty prerogatives have been extended to intellectual property rights with the assumption that the professor will receive credit as inventor as well as author. The inherently one-sided power relationship based upon the right to grant or withhold a degree has thus been further reinforced through the expansion of the mission of the university. If students were to receive automatic rewards upon graduation, perhaps even this extension of the academic feudal system might be acceptable. Since this is no longer the case, the disposition of intellectual property rights has introduced a new level of conflict into the university.

The Ph.D. degree has declined in value as opportunities in the academic system have decreased. A student's best chance at a job and a future career may lie in establishing their own company on the basis of the inventions they have made in the course of their student career. Indeed, intellectual property rights issues have percolated to the undergraduate level as some universities, acting similarly to companies that by contract own the intellectual property rights to employee inventions, have claimed ownership rights to student inventions even without written policies and agreements. A former undergraduate student at the University of Florida, Peter Taborsky, was recently jailed as a result of criminal charges brought by the university, claiming ownership of an invention that the former student had patented. Taking the format of a typical business dispute over the provenance of intellectual property, the university held that the invention was made during the student's academic career and belonged to the university and the company that had sponsored the research. The former student responded from his cell that "the idea for the invention came to him after the sponsorship ended" (*Wall Street Journal* 1996).

The graduate student role has expanded from its feudal format of acolyte to incorporate teaching, research, and invention activities. Pay and status have lagged the reinvention of the role, although a few research units such as the Materials Characterization and Service Center at the University of Puerto Rico pay their students technicians' wages, in recognition of their contribution

to relations with industry. In general, though, the graduate student–professor relationship has yet to be revised from its feudal format, which extends virtually absolute faculty power over the student across the multiplicity of tasks that the latter’s role has accrued, including generation of intellectual property.

Nor is the status of faculty-originated intellectual property entirely clarified. Columbia University has been charged with unfairly appropriating the intellectual property rights of an adjunct faculty member in exchange for honorary faculty status. The economist Dr. Geoffrey Moore, a creator of the leading index of economic indicators, is suing the university for \$23 million in damages. In another instance, a University of California researcher has sued a colleague, charging that corporate research funding, and implicitly any resulting intellectual property, was inappropriately diverted from the university to a private foundation. Despite these disputes, faculty-administration conflicts over intellectual property rights have largely been settled through a three-way split among the investigator, the sponsoring research unit, whether department or center, and the university administration.

The Entrepreneurial University

Some critics of academic-industrial relations would resolve conflicts over intellectual property by having the university retreat behind traditional boundary lines. However, the genie of capitalizable knowledge, whose potential was recognized as early as the seventeenth century, has emerged in the late twentieth century from the “ivory tower” created by the proponents of an ideology of pure research in the late nineteenth century. Moreover, the expansion of academic research has irrevocably changed the function of the university, since potentially commercializable knowledge is created as a byproduct of normal research activities even without new subventions directed toward that purpose. There is likely no return to an earlier era, especially given the university’s external resource constraints and the growing contribution of technology transfer to regional economies and the university’s bottom line. Instead, the university is changing its organization and ideology to accommodate its new role in economic development. Indeed, the role of professor has already been subject to considerable revision through the working out of a new balance among teaching, research, and invention, despite continuing tensions.

Changes within academia are accompanied by the organization of corporatist arrangements among academia, industry, and government, with universities having a greater say in setting the terms of relationships given their increased importance to meeting the goals of their partners. A spiral model of

innovation has also emerged in which basic research spurs industrial innovation and vice versa, as an overlay upon the linear model. Economic development is increasingly based upon utilization of research resources to enhance regional innovation environments. Knowledge-producing institutions such as universities are called upon, or take the initiative themselves, and play a leading role in bringing firms and local governments together to support new initiatives. Universities, both those with long-standing and newly emerging industrial ties, are changing from a mode of separation to one of integration, in organizing their relationships with industry (Etzkowitz 1996). As this change takes place, the triple helix replaces knowledge flows as the appropriate metaphor and model for academic-industrial relations.

The entrepreneurial university, with faculty and administration directly involved in translating knowledge into intellectual property and economic development, attempts to create an industrial penumbra around the university with varying degrees of success. In the following sections of this book, we analyze these developments at three levels. Section I, "The Entrepreneurial University," interprets the changing role of the university in society, the costs and benefits as academia shifts to an entrepreneurial mode. Section II, "The Capitalization of Knowledge," evaluates the viability of different forms of linkage mechanisms that exchange knowledge and technology across the shifting boundaries between academia and industry. Section III, "International Comparisons," analyzes the growth of academic-industry relations in different national contexts and comparatively, across world regions.