THE SECOND ACADEMIC REVOLUTION: THE ROLE OF THE RESEARCH UNIVERSITY IN ECONOMIC DEVELOPMENT

HENRY ETZKOWITZ
Visiting Professor, Department of Sociology
State University of New York
Stony Brook, New York 11794 USA

1. Steady State or Rising Tide?

John Ziman graphically portrays "steady state science" with images of river and battlefield. A river with ever narrowing banks represents the constriction of funding for academic science. A battlefield, with its wounded and dying, and only limited medical resources available, calls forth the image of a triage process in which those who are judged to be savable are rescued and removed from the battlefield while the others are left to die. Indeed, Ziman has described a funding decline in the United Kingdom accompanied by the establishment of a governmental evaluation procedure for departments, the closing down of some, the continuance of others--that is, narrowing banks and triage.

However, in the United States researchers have found alternative sources of support. State governments and industrial firms, each for its own reason, have developed strategic alliances with academic research groups, providing support with the expectation of future economic benefits. Academics and universities alike have acted to capitalize the knowledge they produce, both for immediate financial gain and as a source of long term research support. Finally, as a substitute for an explicit industrial policy, the federal government has used the universities as a surrogate to transfer technology to industry. Royalty and licensing opportunities from federally funded research have been turned over to the universities as indirect payment for service by the universities as technology transfer units. Instead of decline and triage, some existing research efforts have expanded and new ones have been founded.

Thus, the temptation to generalize prematurely from the experience of the United Kingdom, drawing pessimistic conclusions about other countries before examining specific conditions, should be resisted. Certainly the steady state model is especially attractive to academics in the social sciences and humanities because in large measure it represents precisely their parlous circumstances during the past two decades. However, it is questionable whether this model represents the condition of the natural sciences and engineering in the United States since

- non-defense R&D has risen 51% during the 1980s and overall academic R&D has increased from six billion dollars in 1980 to twelve billion in 1987;

S. E. Cozzens et al. (eds.), The Research System in Transition, 109–124.

- the number of state government agencies supporting R&D have increased from nine in 1980 to thirty eight in 1988; and

- industrial support of academic R&D has risen from 4 to 7% (National Science Board 1989, Chap. 4).

It is not only the expansion and diversification of funding sources but the active role of professors in seeking out new sources of support that characterizes academic science in the United States. Although a few disciplinary subspecialties and individual scientists have become subject to the "steady state" of a declining single source of support, many have been propelled forward in their research efforts by a "rising tide" of new external sources of support. This has led to a more complicated organizational structure to manage multiple funding sources and commitments and to an increase in time spent on fund raising, to the possible detriment of more purely scientific work. Nevertheless, while some scientists have chosen, or been forced, to scale back their expectations and activities, others have adopted an entrepreneurial stance and expanded and diversified their research. In this chapter I examine the changing nature of academic science in the United States on three levels:

- the individual scientist who is typically part of a medium sized research group;

- the university, and especially the response of the university administration to funding constrictions; and

- the actions of state and national governments in using the university as an agent of industrial policy.

I argue that the United States research university is in the throes of a "second academic revolution" as it takes on an economic development function, even as institutions of higher education assumed research as well as teaching responsibilities during the "first academic revolution" of the late nineteenth and earlier twentieth century (Jencks and Riesman 1968).

2. Data and Method

To discuss these issues I will draw upon interviews with academic scientists and administrators and archival materials collected during a series of studies that have been underway for the past five years, including:

- university industry relations;[1]

- research groups in academic science;[2]

- the development of computer science as an academic discipline.[3]

In depth, focused interviews with faculty members and administrators and the development of comparative case studies have been the methods of choice (Mitchell 1983, 187-211). The unit

of analysis in these studies has been the department, the research group, individual faculty members, and the university as a whole. Public and private institutions, first and second rank research universities, and institutions with historically strong and with newly emerging industrial ties have all been studied.

3. The Academic Research Group as Quasi Firm

In between "big science" represented by institutions such as CERN and the "little science" of the lone scholar is the mid-sized research group headed by a so-called individual investigator (Etzkowitz 1987). These are typically professors who are supporting at least a postdoctoral fellow or two, several graduate students, even some undergraduates, and sometimes even students at secondary schools--that is, a middle-sized research team. An assistant professor is often supervising a team of three or four people, an associate seven, and a full professor, up to fifteen or twenty persons in some areas of science. At the lower end of mid-sized science, investigators work at the level of between $100 thousand to several hundred thousand dollars in research funds, typically with a main grant from a single agency such as the National Institutes of Health, and perhaps a secondary grant from an additional agency.

The organization of these groups changes as the size increases to about seven or eight members. Professors who were formerly at the bench doing research are typically compelled to remove themselves from the bench to devote virtually full time to organizational tasks. At this level, the investigator primarily spends time

- raising funds and writing proposals;
- going to conferences to make new contracts and to announce results of the group;
- recruiting new group members and handling the personnel problems of old ones;
- writing and reviewing articles;
- serving on review panels;
- managing the intellectual direction of the research from his or her office.

Groups in which the professor is no longer primarily a researcher are what I call "quasi firms." The professor has in fact become a research manager at this scale, even though he or she is still a professor. This is not done from a profit motive, of course; but the group leader's tasks have become largely organizational in nature. Often persons in this situation describe themselves as "running a small business" since they see themselves as responsible, not only for their own funding but for that of several other people. They must maintain the funding of their assistants in order for their research to continue at a competitive level with their peers. If they are in academic departments of liberal arts universities, their salaries are guaranteed, but if they are in medical schools, even that must be raised. Having attained an organizational momentum, it is extremely difficult for such a person to function again as an individual researcher (Vollmer 1962).

Occasionally, in the nooks and crannies of the experimental science departments of a major research university--sometimes literally in an attic--an individual can be found who is working by him or herself, typically in an unfashionable specialty. But this is now a very unusual circumstance. While the notion of the individual investigator is deeply embedded in grant proposals and in the ideology of academic science, the so-called individual investigator is actually operating as a manager, an organizer of a group, and feels that he or she must sustain that group for the sake of the research effort.

In this system, what typically happens under conditions of financial stringency? When funding gets tighter, a higher score is required in the review process of granting agencies in order to obtain a grant (see Chubin, this volume). As the competition increases, an investigator's productivity must go up, in order to keep the level of research going at the quality and quantity that will assure sustained external support. One strategy to improve productivity is to expand the size of the research group. The investigator with three or four assistants feels compelled to expand to five or six. If seven or eight was the previous level, then the investigator has to break through the scale barrier, leave the bench, and go to nine or ten or even fifteen or twenty.

To expand the research group, the investigator must then seek additional grants. Instead of operating with the support of one or two funding sources, the investigator must start cultivating additional agencies. If the relevant federal agencies have been exhausted, then the investigator must look for a foundation and then beyond foundations and other traditional sources of research support to new streams of funding. State and local governments, for example, are often willing to provide research funds to improve the competitiveness of regional industry. The investigator might also engage in collaboration with colleagues from other disciplines and universities to approach new programs in the National Science Foundation with funds for interdisciplinary research centers related to industry. Alternatively, he or she might attempt to move from running a quasi firm to running an actual firm, by participating in the organization of a company that will support research but with the intention of making a product and a profit.

It is usually not the intention of the professor who founds or helps initiate a science-based firm to leave the university and become a fulltime entrepreneur. Typically the goal of most academic entrepreneurs is to participate in research as a consultant to the firm after it is underway, and to play a role in policymaking as a member of the board of directors. Some academics also wish to provide a site for their graduate students and postdoctoral fellows to be consultants, so that they can earn extra money. They believe that this opportunity will help their research group be financially competitive with others, so that it can also keep pace in its ability to attract graduate students and postdocs. Sometimes they expect that their assistants will find consulting opportunities in a colleague's firm to avoid the appearance of a conflict of interest.

In the long term, the hope is that the firm will produce a successful product and that its stock will become valuable. In this event it is expected that there will be a return of funds from the firm to support the professor's research group. That form of financial independence is typically what academic scientists identify as their long term goal when they get involved in the founding of a firm. Of course they are interested in making money personally, but they also express their motivation in terms of a desire to find a stable source of support for their research. Thus, at the level of the investigator, funding constrictions cause an increase in competition leading to the search for alternative sources of support. Under these conditions, some research groups will

decline in size, or even close. However, others will increase their size by drawing upon an expanded range of sources of support. Their survival leads to an overall growth of the academic research system.

4. The Capitalization of the Research University

In the United States, universities have taken on the tasks of economic development. At times this change has been due to external pressures, including funding decline; but sometimes it is the result of internal initiatives. Despite the pressures of constricting funds, few if any institutions have decided to scale down their research programs in the sciences. Indeed most universities are attempting to expand their efforts, at least in selected areas. In the humanities and in the social sciences, on the other hand, academic support has typically been reduced and a few departments (for example, sociology at Rochester and Washington universities) have been closed.

But in the sciences and engineering the goal is to expand the university's research capacity. This has sometimes meant going outside existing channels to obtain funds by direct appropriations from Congress and state legislatures, the so-called "pork barreling."[4] This strategy is used to build facilities not so much for the existing numbers of researchers but, for example (as at Columbia University), to expand the size of the chemistry department. Alternatively, to remain competitive with its peers, the Department of Molecular, Cellular, and Developmental Biology at the University of Colorado, Boulder, is seeking new industrial ties to finance a 50% expansion of the department. Still other universities are seeking new sources of financing in order to establish themselves *as* research institutions in the first instance.

A larger number of universities in the United States are now attempting, with more or less success, to become research universities. Twenty or thirty years ago the discussion was about expanding from a dozen to twenty or thirty full scale, high quality, research universities. Recently, the bulletin boards of the University of Massachusetts at Boston--an institution that is not generally known as a research university--carried notices of a talk given by the vice-chancellor entitled "400 Research Universities?" The clear inference was that if the United States *could* support 400 research universities, than there would be a role for the University of Massachusetts, Boston, among them.

Certainly, that particular school would not be a research university primarily oriented towards traditional disciplines. Its areas of expansion to Ph.D.-level training are targeted to meet regional needs. For example, an environmental science Ph.D. program has been initiated, with a special focus on Boston Harbor. The major universities in the Boston region such as MIT and Harvard do not offer advanced degrees in this field. Thus, the growth strategy for many emerging research universities is to determine areas of regional need where corresponding local sources of support can be identified.

Similarly, economically depressed areas look to research universities to supply new science and technology to revive an existing industrial base. For example, in the early 1980s, most of the forestry school at the University of Michigan was eliminated with one hand, and with the other, the money came back to the university to establish a new Center for Robotics Research. A consortium of business, political, and academic leaders in Michigan had decided upon this strategy

to revive the technology of the American automobile industry. The implementation of that strategy was to set up a research center, drawing upon the faculty of the University of Michigan and other universities in the area, to establish a new set of research programs above and beyond the activities of their department-based laboratories, designed to feed into the local economy.

Universities are also expanding their funding by turning the knowledge produced within the university into capital. This represents the second major transformation of United States higher education. The first transformation occurred in the mid to late nineteenth century when, teaching institutions such as Harvard and Columbia were made into research institutions and new research universities such as Johns Hopkins and Chicago were founded. This initial transformation was, in part, a response to the limited availability of funds (Geiger 1986).

Instead of developing a separate set of research institutes, as was the practice in Europe (see Block, this volume, for the German case), basic research was located in academic institutions. Professors, already paid for teaching duties, assumed research responsibilities as well. With modest financial support, graduate students assisted the professor at the same time as they received their training. This system was productive and cost effective, in part due to the low rates of pay and the high level of results obtained, but also because of the flow of people through the system. Students entered the laboratories and left with their degrees within a relatively few years. A continual stream of new people brought in new ideas, in contrast to the institute model--a more stable structure, where ossification can easily set in unless there is a continual expansion of the institute bringing in new people. Continual expansion, of course, requires a much higher level of funding.

In the 1920s, a systematic program of industrial ties were introduced at MIT, also in response to constricted budgets. During the post World War I inflation, MIT was faced with a dilemma when it lost its funding from the Commonwealth of Massachusetts. (The argument that it had Massachusetts in its name was not sufficient to convince the legislature it was a state institution. They thought it was essentially a private university in the American sense.) Despite this crisis, MIT decided not to accept an offer of merger with Harvard, believing that the Institute's identity would be submerged or even lost as Harvard's engineering school.

Instead, MIT proposed to solve its financial problems through ties to industry. Having already received recognition from major corporations as a provider of engineering graduates who had risen to high positions and as a source of expertise through faculty consultants, MIT attempted to capitalize on the ties that it had with industry and get support from companies. They proposed to do this through regular payments that firms would make to the university in exchange for increased access to the research of professors. This effort was called the Technology Plan. Funds came in from companies, at least temporarily. The Technology Plan soon largely disappeared, however, partly because the companies had already made their own arrangements with professors to consult and felt that they were being asked to pay double by giving the university a fee in addition to the professor. Most thought of their support for the Plan as a one time donation to put MIT back on its feet financially, not as a permanent subvention.

Nevertheless, an important outcome of the Plan was the establishment of an office within the administrative structure of the university to negotiate contracts with industrial firms. Despite the withdrawal of many firms from the Plan, there were enough contracts for the office to manage

to allow it to stay in existence. In 1940, at the onset of World War II, the leadership of MIT and other academic institutions convinced President Roosevelt and the federal government that academic science could be a major contributor to the upcoming war effort and therefore merited an independent agency. Successful in their efforts, these academics became the leadership of a wartime governmental research apparatus, the Office of Scientific Research and Development (OSRD.

OSRD was an astonishing accomplishment, considering that the scale of university research in the 1930s, with the possible exception of the cyclotron facility at Berkeley, was nowhere near the level of major industrial firms such as Bell or General Electric. The lead in wartime research, if it had been decided by existing capabilities, should have been taken by the major industrial laboratories. However, academics took the initiative in organizing a research scheme, and brought industrial research leaders into their activities in a secondary status. With the approval of the federal government, the academics were placed in key organizational positions, and research contracts flowed to the universities.[5]

How were these contracts arranged at MIT? The Technology Plan office was turned to a new purpose: it was directed to negotiate the terms of the new research contracts with the government. When other universities took on contracts with the government, they duplicated MIT's office and followed the formats established by the MIT contracts. This was the origin of the contracts and grant office as the mediator among the university, industry, and government, negotiating arrangements acceptable to all sides. Today a contracts and grants office is commonplace at every university and even at teaching colleges that want to arrange some research. More recently, those offices, which in the postwar era dealt almost entirely with government, are adding another person or two, or a new division, to negotiate contracts once again with industry.

There have also been some additional innovations in university administration to organize arrangements between university and industry. In addition to a contract office, universities often set up a technology transfer office, sometimes called an Office of Science and Technology. Such an office is typically administered by a Ph.D. scientist who has worked in industry and is knowledgeable about the industrial sectors relevant to that university. Such a person is hired by the university to seek out marketable research that professors are doing, research that has commercial significance that the professor has not recognized. The administration announces the establishment of the office and encourages professors to make contact when they think they have results that might be patentable or have other commercial potential. The existence of such an office means that a professor does not have to have an interest in commercialization for their research to be marketed. The university administration will attend to those arrangements. But professors are encouraged to recognize the commercial potential in their research as part of their job. They are not expected to form firms out of their research, although that is now typically welcomed. However, in addition to grants awarded, papers published, and students advised, it is considered advantageous to have a patent or two on one's *curriculum vitae*. Faculty are aware that the university administration is interested in the commercialization of research: why not accommodate them in expectation of recognition at tenure and promotion time? Thus, the university incorporates an office, usually headed by a former industrial scientist, with the purpose of finding, patenting, and licensing marketable research.

By thus "capitalizing" academic research findings it is believed that the university will have an improved ability to shape the direction of its research effort, since funds generated from previous research would be used to fund new research. The expectation is not that the resulting income will replace government funding to any significant degree. Almost all universities expect the federal government to remain their primary source of research support and will fight to maintain or increase their share of federal research funds by one means or another. Rather, the expectation is that in the medium term, patent and licensing income could add an increment of perhaps 10% to the research budget of the university. This would be funding that is not earmarked, as grants ordinarily are; rather, administrators and professors could exercise discretion in spending these funds. In any event, technology transfer offices are relatively inexpensive to start, soon at least pay their own way, and are proof that the university is making a serious effort to contribute to economic development.

As part of the growth of an economic development function in the university, administrative offices are turned to new uses. During the student protests and antiwar demonstrations of the 1960s, some American universities hired attorneys to go to court, gain injunctions, and get the students out of the administration's offices. But as in many organizations, things continue on a course that has been established even when the original reason no longer obtains. Many universities found that having attorneys on the staff of a university was useful for a variety of activities calling for negotiating skills and the establishment of understandings across institutional spheres such as university-government and university-industry boundaries. Some of these attorneys have moved on to high administrative positions in the academic world, including university presidencies. For example, the former attorney at Washington University, St. Louis, in the early 1970s, is now president of the University of Miami and has announced plans to transform that institution into a major research center.

In the 1980s, a new role has emerged for university attorneys as patent advisors. Even when they do not themselves make the arrangements to patent, they function within the university as the interface between faculty, technology transfer offices, and patent law firms hired by the university to secure intellectual property rights. Thus, an existing legal office has been transformed to support the university's new economic development function. There is a shift in direction, from the social control activities that originally brought lawyers onto the academic scene, to their present day work protecting intellectual property.

The instances discussed thus far are means of capitalizing research and translating it into economic goods. There are often other resources that the university can capitalize and use to improve its financial standing. For example, in the United States many universities were established on large tracts of land. Indeed, the use of land as the economic base of the university was the fundamental concept of the land grant legislation of the 1860s. A large tract of federal land was provided to one or more universities in each state that assumed certain public responsibilities. Much of the land was then sold and the funds were used to build the original campus buildings. In the mid and late nineteenth century, the federal government did not have the financial resources or the political capability to support directly the development of an academic system geared to the support of the major industry of that era, agriculture. But it was able to use land, a valued national resource, to achieve that purpose. Similarly, the federal government has recently turned over patent rights from federally funded research conducted at

universities, allowing these academic institutions to sell research results to support the future development of their campuses.

In the early postwar era, Frederick Terman, Dean of Engineering and Provost of Stanford University, developed the strategy of using surplus campus land as the basis of a fund raising strategy. He persuaded the university that it would not need all the land from the large farm on which it was situated for the future development of the campus. Instead part of it would be developed as a shopping center and another part as an industrial park to provide a steady stream of income for the university. In addition to funding the university, the industrial park served the dual purpose of housing a broader technical community for the academic departments to interact with, as well as providing a convenient site where firms based on university research could locate.

The income from the shopping center and the industrial park made possible Terman's much emulated "steeples of excellence" strategy, building up selected departments within the university. Terman followed the receipts coming in from the shopping center, and as the funds built up he would say to himself, "Now I can hire two or three more professors." It is not unusual for universities in the United States to provide initial research support from its own funds for a faculty member to build up a research group or establish it in a physical facility. Real estate development brought in an increment of funds in addition to what was taken in from the federal government, alumni, and other financial supporters that enabled the university to make additional appointments and provide faculty with extra research support. Stanford's innovative funding strategy enabled it to transform itself from a middle rank university in the prewar era to a leading institution in the postwar era.

An industrial park also provided financial support for Princeton University. The Forrestal Center, established on university-owned property, transformed a sector of central New Jersey from an exurban residential area into an industrial research corridor. It is significant that, during the 1980s, such ventures, formerly peculiar to a very small number of institutions (whether contract offices at MIT in the 1920s or industrial parks at Stanford and Princeton in the 1940s), have spread to a much broader range of universities. In 1980, 19 universities had research parks; in 1989 there were 76, with a total of 1700 firms located at these sites (Etzkowitz and Peters n.d.). There have been many questions raised about whether this is a viable financial strategy for universities, but the amount of funds going into university-related real estate development (not only university funds, but funds that come from state and local governments and private developers) indicate that this is now a permanent feature of the research university.

Another indicator of a fast-spreading phenomenon is the number of people who enter a growing field from other areas. An administrator of one of these university research parks, formerly a director of student affairs, had moved into general university administration with responsibility for developing a research park. In the early days of his tenure he received a call from industry asking if his university had an incubator (the technical term for a facility to encourage development of small firms from a university campus). Unaware of the special sense of this term he made a referral to the poultry science program at the state's leading agricultural university. Several years later, he has successfully organized a research park on part of the university's campus. The park has attracted the research department of a major telecommunications firm as an anchor facility. This initial success will then be the basis for drawing in additional technical firms to the Park.

It is expected that this development will have the further effect not only of improving the financial picture of the university and the surrounding community but also of creating a larger technical community adjacent to the university. In this model, university researchers will interact with their firm counterparts and there will be an expansion of academic departments in selected areas that are relevant to the region's technological development. It will also lead to the development of a more complex technical structure in the region and an ending of the isolation of university researchers from industry. This is expected to result in commercial involvement by university researchers even when they do not want to become directly involved with the commercial process itself. Thus, the university administration has put into place structures that will lead even those academics who are currently not interested into making industrial ties, because people will come to them offering consulting opportunities.

Beyond even the establishment of research parks, there is an additional emerging trend in academic-based economic development: the university as venture capitalist. Only a few universities thus far have taken the initiative of providing capital from their endowment to help establish a firm, usually based on research conducted by a faculty member. This is one step beyond accepting a block of stock in a faculty-initiated startup firm as payment for the university's interest in the technology being transferred from campus. In both of these models the university looks to the future growth in the value of such stock to build the value of its endowment.

Historically, it is interesting to note that in the United States, an academic institution, MIT, was involved in the invention of the venture capital firm as an institutional form. In response to the economic constrictions of the Depression, in the 1930s a consortium of business, political, and academic leaders established a forum to develop a strategy for economic revival of the New England region, which had been suffering a long term decline of its economic base from at least the turn of the century. President Compton of MIT was invited to participate in these deliberations, having just given up on an unsuccessful effort to persuade the federal government to support academic research. In the egalitarian tenor of that time, the notion of supporting elite institutions was rejected. Federal funds that did come to support academic science came from more general programs for the unemployed (and they did indeed have the positive effect of keeping a large number of graduate students in the system).

In the course of the discussions on reviving the New England economy, the idea arose of utilizing the technological resources of the region's academic institutions to improve the economic viability of area firms. At first the notion was to try to revive existing firms, but it was realized that too many had depleted their capital, lacked technical personnel, or were too far removed in their businesses from emerging areas of technology for the strategy to be effective. As a result, the concept was extended to include the creation of new technically-based firms formed from university research, but this emerging initiative was interrupted by the onset of the second World War.

Immediately after the war, President Compton, together with some of the leading members of the financial community in Boston, began another effort. They founded a venture capital firm, the American Research and Development Corporation (ARD), whose goal was to provide seed funding for new technically-based companies. The MIT Treasurer's Report for 1947 lists one investment, totally different from all the other investments because it had a value of zero. That

was the value of the ARD stock in MIT's portfolio. Compton also obtained investments from other universities, insurance companies, and financial institutions in Boston, which at that time were using their capital largely to fund major industrial companies in other parts of the country. The plan for technical firm formation was not created in a vacuum: there had been instances dating from the late nineteenth century of firms formed out of university research. What was new was a mechanism to organize systematically what had previously been an individualistic and happenstance occurrence.

Compton and his collaborating institutions wanted to draw upon the technical and administrative expertise of MIT and Harvard to build new technically-based firms. Thus, ARD brought together two streams of people from the academic world:

- professors from MIT as technical advisors and graduates as employees to seek out new technologies, and

- a faculty member and graduates of the Harvard Business School to run the business side of the firm.

ARD staff members visited universities to seek out sources of marketable technology and evaluated proposals that came into the firm. The formation of new firms took place on a relatively small scale in the late 1940s and early 1950s. In the mid 1950s, ARD was introduced to a research group at an MIT laboratory that had been unsuccessful in a competition for funds held by the armed forces for computer development. When a competitor system was chosen, this group would have to either disband or find an alternative source of support. The connection to ARD resulted in a plan for a new corporation. The researchers soon left MIT's Whirlwind Project to form the Digital Equipment Corporation. The growth of this firm represented the first major success for the proponents of a venture capital strategy of developing new firms that would have an impact on reviving a regional economy. In succeeding years ARD became the model for other venture capital firms, some founded by former employees, and for federal legislation encouraging the establishment of new venture capital formats.

Thus, in the United States, the venture capital industry had its origin in university involvement in economic development. This event is now far enough in the past that few people, even on the financial side of MIT, are aware of the role that their predecessors played in the formation of the venture capital industry. Upon learning of this history, a member of the MIT Treasurer's office realized why he was always so warmly received at meetings of venture capital groups. Although MIT had long since sold off its investment in ARD, MIT is currently taking an active role as a venture capitalist. It is willing to help fund new firms established by faculty or alumni, as well as participate in deals brought to it by venture capital firms.

Washington University (St. Louis) has hired a venture capitalist as part of its administrative staff to help decide on what investments to make. Given the publicity and communication about financial innovations at universities, once something is tried, it tends to spread very quickly. The research park concept spread from 19 sites to 76 within a decade. The concept of the university as venture capitalist is likely to spread in a similar fashion within the next decade.

In many ways the university is especially well suited to act as venture capitalist. There are few institutions in the United States with extensive financial capabilities that also conduct long range research. Moreover, since the university lacks stockholders and is not subject to Wall Street pressures for high quarterly returns, it can take a long term perspective on its investments. Even most venture capital firms do not take a long term perspective, funding only the middle (so-called mezzanine) and later stages of new firm development. Furthermore, many venture capital firms concentrate on nontechnical areas and do not have staff with relevant expertise in emerging technical areas. A relatively small number, perhaps only ten of the several hundred U.S. venture capital firms, provide seed funding for new technically-based firms.

With the acquisition of venture capital expertise, universities are likely to fill the gap that exists in technology development and capital formation. The nature of university research activities insures the availability of expertise for technical evaluation of potential investments. Given the size of their endowments and their insatiable need for more funds, universities are likely to take a more aggressive investment strategy and commit a (relatively small) portion of their endowments to venture capital activities. There is one university, of course, that has committed a very large proportion of its endowment to an investment in a single biotechnology firm: Boston University. However, very few other schools are likely to adopt such a risky strategy. Most universities will act more conservatively and use only a relatively small percentage of their endowment for venture capital investments. In any event, this stance is merely the latest stage in a long term shift of universities, over several decades, to a more aggressive, riskier, investment strategy: from preferred stocks, to common stocks, to financial instruments at the premarket stage of capitalization.

5. The University as Surrogate for Government Industrial Policy

Another phenomenon emerging in the university, the establishment of multidisciplinary research centers, takes me to my third level of analysis: the role that state and federal authorities are playing in reshaping both private and public research universities to contribute to economic growth. One major new source of funding for academic research is from the state governments interested in development for their regions. For example, Columbia University's Center for Advanced Technology (CAT) is one of ten CAT's partly funded by New York State's Science and Technology Foundation. It receives $1 million each year from the state, and close to three times that amount from corporate sponsors, to promote technological cooperation between industry and academe (Finance 1989). CAT computer scientists are integrating work on financial industry problems such as transaction processing into their research programs on parallel processing, fault tolerance of large scale systems, and distributed software. The faculty researchers are primarily funded by federal agencies, but through the CAT they receive increments of state and industry support. Instead of working on "toy" models or military problems, the researchers are applying statistical models to trading patterns and parallel computing to process trades in mortgage securities. Thus their focus of attention has been shifted to a major local industry.

In 1987, the United States had $1 billion in state government support for research and development at research universities (National Science Board 1990). Again, in a relatively short time, such activities have become commonplace and widespread. A network of state government science advisors keep in regular contact by telephone and occasional meetings, so when a

successful technique is invented it is soon replicated. Even remote states not known for their technological capabilities have attempted to develop niches for themselves in technological development. A recent advertisement in *Science* sought a director for an industrial development foundation in the state of Alaska, which has announced plans to concentrate on technologies with special application to cold climates. The current 38 state programs will likely soon be 50.

Such agencies provide supplemental research funds for individual investigators; sometimes they fund entire research centers relevant to regional economic concerns. New technical communities are created, integrating academic and industrial researchers. These recreate on a more formal and funded basis some of the ties that existed in the prewar era when academic and industrial technical groups were smaller and less likely to interact solely among themselves (Reich 1985). In those days, physical distance was a positive factor in university-industry interaction. Researchers at Bell Labs on West Street in Greenwich Village and at Columbia University in Morningside Heights could take the subway to each other's colloquia or journal club meetings.

Now ties are more likely to be formally negotiated and contractual in nature, at least at the outset. On the one hand, at the center discussed above, a faculty member said that with respect to business, "Columbia has ideas, technology, facilities. We interact with Citicorp to understand their problems and develop prototypes of solutions." On the other hand, a bank representative noted that Citicorp, "selects problems that have mutual interest and potential payoffs for us" (Finance 1989). Behind the new ideological facade of regional economic development, academics are bringing in funds to support their basic research projects. Academics and business are also leveraging their research dollars with subsidies from the state government. At one and the same time, the research frontier is advanced and practical problems are solved, such as the analysis and improvement of fault tolerance in automatic teller systems. If both types of progress were not possible, the edifice would soon collapse.

At conferences at the state capital, academics are oriented to elementary political tactics, such as inviting their local representatives to the state legislature to announce a new grant. They are also oriented to state government concerns such as job creation and improvement of public education. Academic scientists at high-ranked national research universities, who formerly related solely to program managers for NSF or the Defense Advance Research Projects Agency, are learning the ropes of state and local political customs as they maintain, or even seek additional sources of funds to expand, their research programs.

On the federal level, university-industry-government ties were built into the academic structure as an outcome of the debate in the late 1970s, during the Carter administration, over whether the United States should have an explicit industrial policy. The debate, not surprisingly, came to an end with the onset of the Reagan administration. Nevertheless, a United States industrial policy was established *sub rosa*, using the university as the vehicle. The patent rights to federally funded research at universities were reserved to the government to dispose, and typically the government did not exercise its rights. Theoretically the knowledge was freely available to any interested party to commercialize, but without the ability to protect an investment for a period of time, open access in effect meant little interest.

In 1980, The Stevenson-Wydler Act turned over the results of research funded by the government to the universities to commercialize. When Congress turned these rights over to the

universities, it did not necessarily mean that universities would do any more than the government did to exercise them. However, the publicity about one early firm started under the new policy (Genentech), which experience a huge increase in value of its stock in a single day, illuminated the potential value of academic research, and caught the attention of university administrators. That summer, or soon thereafter, the patent policy of many universities was changed, giving universities control of the patentable knowledge emanating from university-sponsored research. There were complaints the next fall by faculty who had traditional arrangements for transferring knowledge to large firms in exchange for gifts to their departments. Nevertheless, administrators took the position that they would now control and market that knowledge. A share would be reserved, of course, for the department and the investigator; but the university itself would act as primary capitalist in arranging the transfer of knowledge. Thus, the increased effort to patent discoveries emanated from within the universities as a result of funding pressures and in response to changes in national policy that assign the university a larger role in economic development.[6]

6. Conclusion: The Second Academic Revolution

Finally, it should be asked: Is this new expectation of the university realistic? Or is it merely a passing wave? Will it disappear, or is there substance to the notion that the university will play a more central role in economic development? This question is, of course, of great interest to the National Science Foundation. If it is true that academic research in the sciences and engineering is of great economic consequence, there will be an additional measure of political support for the argument that the National Science Foundation budget should be doubled in the next several years. The Reagan administration accepted this goal, but Congress has not yet fully passed the funds to realize it. Congress gives several percent more each year, but not enough to constitute a doubling in the near term. However, if it is true that the university plays, or could play, such a significant role in the economy, then there would be justification for a new social contract with the university, replacing the one with the military that is ending as the Cold War winds down, bringing with it once again broadly increased streams of funding from the federal government.

After studying seven industrial areas, Professor Edwin Mansfield (1990) has made what he regards as a very preliminary and tentative estimate of the social rate of return from academic research. His findings suggest that there may have been about a 28% return on university research. The return is higher when companies themselves are heavily involved in the research and are aware of its uses. But even when they are not, there is still a substantial rate of return. Even if the time period for a return is collapsed to a shorter period, the rate of return is significant. It can be predicted that this study will both spark a debate within the economics of technology on the role of basic research in technical change and also be much quoted in Congressional debate by proponents of increased research funding for federal agencies.

So research itself provides the final legitimation for this second academic revolution in the United States. The first academic revolution was in the late 19th century when research became a legitimate function of the university. In that era there were many objections that research activities were improperly taking professors away from their traditional role as teachers. Nevertheless, that transformation took place. Now we are undergoing a second transformation in which economic development is added to research and teaching as a legitimate function of the university. Now these three functions will be integrated. Teaching will not disappear from the

university: it is too cost effective. Students are not only junior researchers, but also future alumni who make philanthropic donations. Those few universities in the late 19th century that tried to do without undergraduates soon thought better of it and brought back or re-emphasized their undergraduate colleges. In the late twentieth century, even as universities become much more explicit agents of economic development, as part of their nation's and regions' industrial and science policies, they will also retain their traditional functions of research and teaching.

Notes

1. Supported by grants from the National Endowment for the Humanities, the National Science Foundation's Science, Technology, and International Affairs Program and Ethics and Values Studies program (with Lois Peters).

2. Supported by the State University of New York Research Foundation.

3. Supported by National Science Foundation's Computer Science and Science Resource Studies Programs (with Lois Peters).

4. See Teich and Chubin, this volume, for other discussions of pork barreling. This term is used in the United States to describe the distribution of large government-supported projects as political favors. Although they are a recent innovation in the academic world, such subventions are part of routine politics in the United States, where a legislature by tradition makes available a certain amount of funds for a legislator's pet projects that can also be shown to serve a public purpose. Naturally, the more powerful the legislator, the greater call that can be made on such funds. Thus, new institutes may be named after retiring senior legislators such as the McCormick Institute at the University of Massachusetts, Boston. Universities in the United States are also making broader claims to special appropriations, hiring lobbying firms to help make the case that a national treasure will be lost if a facility for a leading department at a major research university is not funded, or alternatively, that a second rank university has been excluded from its "fair" share of support through normal channels due to geographical discrimination. Nor is this approach to the public treasury entirely new. In the early postwar era, the University of Chicago, often referred to as an institution that would not engage in such direct political intervention, successfully obtained federal funding by special act for a series of research institutes that allowed the university to construct new facilities and institutionalize its expanded wartime research capacity in physics and related disciplines. The recent stream of individual legislative decisions to fund construction of facilities at particular universities has created a de facto federal policy (National Science Board 1990).

5. To create large scale research capabilities in university settings, faculty were drawn from across the country to laboratories and projects at a few major universities such as MIT, Johns Hopkins, and Chicago. This pattern was an alternative to either decentralizing the research to the universities where the professors resided or concentrating and isolating it in military laboratories. There was, of course, the notable exception of Los Alamos; but even that laboratory was, in effect, led by academics.

6. For further discussion see Etzkowitz, n.d.

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