Universities as engines of R&D-based economic growth: They think they can

Irwin FELLER

Institute for Policy Research and Evaluation, The Pennsylvania State University, University Park, PA 16802, U.S.A.

Final version received October 1989

Two issues raised by increased participation of universities in equity arrangements designed to commercialize faculty research are addressed: (a) the effects that an increased emphasis on patenting faculty research and on enhancing the commercial value of these patents has on the characteristics of academic research, net revenue streams, and existing channels through which academic research enters the market, and (b) processes of institutional change and imitation, whereby changes in the policies of elite research universities exert competitive and emulative pressures on other institutions.

Increased efforts by universities to foster the commercialization of technological innovations erodes the singular position of institutions of higher learning in the United States. Based on past performance, there is little reason to expect that a substantial reallocation of faculty effort towards commercially oriented R&D will generate appreciable net revenues for other than a select number of universities. These ventures also serve to shift academic researchers from the social roles in which they are most efficient, as suppliers of a collective good—scientific and technological knowledge.

> "Just as very few men are both capable business managers and ingenious inventors, so few are at the same time ingenious inventors and exalted altruists. Some twenty years ago a university professor devised a method for measuring with accuracy the content of butterfat in milk. The device, if patented, would doubtless have yielded him a very handsome income. The inventor gave it freely to the public, saying modestly that to do so was but part of his duty as a servant of the people and it has come into use the world over. We call his conduct noble; but our very recognition of its nobility is an admission of its rarity" (F.W. Taussig, *Inventors and Money Makers* (1915) [58]).

* I am indebted to William Zumeta for his comments on the paper at its presentation at the Association for Public Policy Analysis and Management's 1988 Research Conference and to those by this journal's reviewers. On subjects beset with considerable debate, authors must underscore their sole responsibility for the views expressed in their writings.

Research Policy 19 (1990) 335–348
North-Holland

> "Indeed, it is a fairly safe test; work that has a commercial value does not belong in the university" (Thornstein Veblen, *The Higher Learning in America* (1917) [64]).

1. Introduction

Universities are beginning to move beyond "new research and development alliances and partnerships" and are entering into equity arrangements that will further the development and commercialization of their faculty's research. This new(er) institutional stance reflects what has been termed "active technology transfer", an "aggressive reach into the research laboratory [where they] actively search[ing] for commercializable new applications of technology and then seek[ing] to develop the product or process, with an associated business entity, through early stage commercialization" [67, p. 61].

These initiatives are seen as serving several constructive ends. In industries where competition is characterized by rapid rates of technological change, the search for commercially significant new knowledge may be closely linked with significant advances in scientific and technological knowledge; increased university involvement in commercial activities may supplement existing institutional mechanisms (e.g. research grants, consulting) through which market signals about the projected economic value of new findings are transmitted to faculty. "Commercialization" and academic "contributions" to scientific and technological knowledge thus may be joint products of research; at a minimum they need not be antithetical activities.

Universities, within stated policies, already bestow institutional approval (and indeed commendation) on faculty successes in securing exter-

nal research support and consulting relationships. The development of research teams has already given the character of "quasi-firms" to academic research, with academic scientists often eager and willing to direct or participate in R&D programs aimed at commercial application [12]. Richter has suggested that university scientists with considerable consulting practices first incorporate themselves for tax purposes; then, having taken this step, they "...easily move beyond ordinary consulting activities, into additional entrepreneurial activities" [47]. From these perspectives, institutional participation in equity arrangements primarily constitute improved methods of increasing the relative-shares that faculty inventors and universities accrue from the economic profits brought by their contributions to knowledge. As illustrated, however, by Harvard University's plan to form limited partnerships that would permit it to pursue the commercialization of its medical school faculty's research, these initiatives also raise new issues and compound others.

In 1982, assessing the appropriateness of the university's growing involvement with industry in R&D partnerships, Derek Bok, President of Harvard University, observed that the most controversial aspect of collaborative partnerships was the university's decision to either assist or not assist its professors in the formation of companies that would exploit their discoveries. Weighing the pros and cons of these partnerships, Bok concluded: "All in all, ...the financial advantages to the university appear more speculative than heretofore supposed, while the dangers to academic science from participating in these ventures seem real and severe" [7, p. 166]. On 15 September 1988 an article in the *New York Times* entitled "Harvard to Seek Research Profits", reported the following: "In an important policy reversal, Harvard University has decided to raise money for investments aimed at bringing faculty members' research to the marketplace and making a profit for the school" [42, p. A21]. Under the reported proposal, Harvard was to raise $30 million from six to eight institutional investors in order to form a series of limited partnerships. These partnerships would review research projects by medical school faculty and identify marketable developments. Once the faculty and the medical school agreed to work with and through the partnerships, these projects would receive further development and commercialization. Harvard would receive 10 percent of the companies' profits after the initial investors were paid.

This paper focuses on two broad sets of questions that stem from Harvard's action. [1] One set relates to the economics of technological change, or more precisely, the effects that changing university participation in equity arrangements to commercialize faculty research may have on the role of universities as suppliers of scientific and technological knowledge. Included within this set are both macro-level and micro-level questions. The macro-level questions center on whether the assumption by universities of this expanded role will increase or decrease the rate at which academic research, considered now in the aggregate to encompass all fields of knowledge from all universities, is assimilated into commercially marketable products and processes. Underlying this macro-level question is the perspective that the conventional tripartite distribution roles of universities, firms, and government as sponsors and performers of basic, applied, and developmental research do not represent an inherently "natural" state of affairs. Rather, these roles represent an historic (short-run?) equilibrium that has evolved from an error-strewn search by each participating institution for a means to accomplish its specific objectives.

The micro-level questions include a consideration of the magnitude and distribution among universities of net revenues from technology-

[1] Not considered in this paper is the relationship between more extensive university participation in the commercialization of intellectual property rights and the quality of graduate and undergraduate instruction, in particular the effects faculty involvement in activities related to commercialization may have on the time allocated to instruction. The character of the debate concerning this relationship is suggested on the one hand by Utterback's findings that basic research, rather than being significant as a direct source of innovation, "plays a critical role in the production of knowledge and enters the process of innovation indirectly by means of education" [63, p. 622] and Blumenthal et al.'s findings that faculties with industrial support believe such support enhances career opportunities for students. In contrast, Fairweather, although noting that "In principle, universities can pursue liaisons with industry while simultaneously attempting to improve instructional quality", nevertheless criticizes academic leaders for ignoring the diversion of faculty efforts away from instruction that follows upon the pursuit of economic development objectives [13].

licensing operations, and an identification of the (implicit) economic assumptions contained within emerging university technology-development strategies and revenue projections.

Second, Harvard's change, although in many respects replicating actions already taken by other universities, raises questions about the propelling force and dynamics of institutional change within and among research-oriented universities. Among these questions are the following:

(a) To what extent do prevailing interpretations of current trends in expanded university–industry–government partnerships—which tend to present universities as being under inexorable budget pressures or, in the case of public universities, political pressures to become partners in a state's economic development thrust [1,53], to take on expanded roles in the commercialization of new technology—accurately reflect the degree to which universities are, in fact, masters of their own fate?

(b) How do changes in missions and policies diffuse among research-oriented universities?

One conundrum warrants attention before these two questions can be addressed. University movement toward direct participation in the commercialization of faculty research runs counter to a preponderant set of findings which suggest notable peaks amidst a vaster plain. Academic research, while contributing to the rate of technological innovation in the private sector either through the transfer and development of basic research findings or as the basis of spin-off firms [63] has been linked infrequently to commercializable products. Nelson, for example, in his review of the Levin et al. survey of the means by which firms establish private property rights to R&D-based knowledge, writes that: "...university research rarely in itself generates new technology; rather, it enhances technological opportunities and the productivity of private research and development, in a way that induces firms to spend more both in the industry in question and upstream" [40, p. 188]. Similarly, Roberts and Peters report that most technical universities have "little effect, even few instances of commercially-oriented information transfer, upon neighboring industrial firms" [48, p. 109]. Tornatzky, Solomon and Eveland's study of university–industry cooperative R&D programs in the fields of information technology, materials, and biotechnology, found "limited evidence of profound commercialization success emanating from the research programs' studies" [59, p. 24]. Larsen and Wigard report similar findings in their study of collaborative R&D in microelectronics [24].

The U.S. General Accounting Office's survey of the firms participating in NSF's Engineering Research Centers (ERCs) also highlights how little firms expect by way of patentable outcomes from their support of university research. Of the 15 reasons listed for the participation of a company unit in an ERC, the opportunity to develop patentable products was the least stated reason, with only 8 percent of the respondents ($n = 168$) rating it as extremely important or very important [61, p. 55]. By way of contrast, and serving to highlight the expectations of the private sector towards the commercial utility of academic research, 89 percent of those surveyed cited the match between research at an ERC and the firm's interests as being important or very important to its participation, and 88 percent of the respondents said that the ERC was doing state-of-the-art research that interested the firms. Also illuminating the implicit strategy of many firms was the importance they assigned to their ability to multiply research investments with money from other ERC participants: 48 percent of the respondents cited this factor as extremely important or very important. This latter finding suggests that firms invest in ERCs, as they have in university-based consortia or affiliates programs, in order to support generic research, a more useful concept than "basic", "targeted basic", or even "applied" research, and then rely upon their own scientific, technical, and marketing resources to vie with other firms in the conversion of that knowledge into products and processes.

Economists who have studied the processes of technological innovation tend to view cases in which academic research has directly led to economically significant technical advances (and thus either generated or have the potential to generate sizeable income for the faculty and their home institutions, such as the Cohen–Boyer patent on gene-splicing) as infrequent events that require the following conditions: (a) scientific advances that have "industry-creating" potential; (b) a large (dominant) role for academic scientists as the source of this new knowledge; and (c) a ("venture") capital market willing to invest in the

long-term economic potential of "basic" research.

But these occurrences, widely associated with scientific, technical, and economic developments in microbiology and microelectronics (and more recently in the ferment over superconductivity) are seen by many scholars as a short-run phenomenon; indeed, to cite the example of the biotechnology industry which precipitated much of the past decade's focus on university–industry R & D partnerships, industry representatives now note that patterns of university–industry arrangements are shifting away from direct investment in long-term university-based research programs, towards consulting and contract research [60]. The prominence enjoyed recently by academic scientists in these selected fields is not unlike that described in the early technological histories of synthetic chemicals or computers. As B. Williams, writing about this process in the organic chemistry and electric industries during 1880–1910, observed, manufacturers were first dependent on the knowledge of academic chemists and physicists for the initial industrial innovations:

> "but as the innovations increased and diffused and the number of graduates increased, the successful firms established their own research departments and became less directly dependent on university scientists. Although over the years the indirect contributions of academic scientists have grown in importance, industry became less dependent on their direct contributions" [69, pp. 151–152].

Williams advances other explanations for the diminishing prominence currently enjoyed by academic researchers:

> "The final stages of development and design work leading to innovations normally need to be conducted in close co-operation with staff in production and marketing; there are still many innovations which generate substantial financial losses; and there are still significant differences in the value systems and patterns of organization which promote success in basic research and in the use of new knowledge in the production of goods and services. Given the current nature of science and technology and the conditions of industrial innovation, the case for forcing major changes in objectives and organizational patterns in the interest of higher rates of innovation and growth is not strong" [69, p. 158].

Something is obviously askew between this analytical and historical recitation and current, quickening trends among research universities toward active participation in the commercialization of faculty-generated research.

The boundary markers that empirical accounts or economic logic would seem to place on the extent of the universities' effective participation in the commercialization of academic research are being moved. Identifiable legislative and legal changes affecting the appropriability of intellectual property rights, e.g. the Patent and Trademark Amendments Act of 1980, and the increased willingness of investors to take risks, provide a plausible *a priori* case for the economic effectiveness of these new coordinates, as they successfully serve to accelerate and/or increase the conversion of academic research into marketable innovations. The markers, however, also may be moved by attitudinal changes akin to speculative bubbles on the part of entrepreneurial faculty and academic administrators, and by imitative processes among universities. In either case, universities, like the little engine laden with gifts for the boys and girls on the other side of the mountain, "think they can" succeed.

2. The economic aspects of university involvement in the commercialization of research

A university's "aggressive" technology development strategy involves encouraging (and assisting) faculty to seek patents for their research more assertively, and to undertake (relatively) more patentable research; to more actively seek to license patents assigned to the institution; and to enter into more equity arrangements with firms wishing to commercialize faculty research.

Institutional moves to review and revise patent and licensing policies are widespread among American universities [2]. Increased institutional emphasis on the patenting of academic research raises at least three distinct, albeit related, items: (1) the number, rate of increase, and distribution of university-generated patents among fields of knowledge; (2) the income stream generated for

universities through the licensing of patents and/or participation in firms that seek to commercialize those patents; and (3) the impacts that both (1) and (2) have on the characteristics of academic research, the rate of diffusion of academic research into commercial uses, and the processes by which this transfer occurs.

That universities are actively seeking to increase the patenting activity of their faculty is manifestly shown in U.S. patent data, surveys of organizational changes within universities, and the increased number of internal university study groups charged with reviewing and revising institutional patent and technology transfer policies. U.S. Patent and Trademark Office data reveal an increase in the number of patents issued to U.S. universities. Between 1969 and 1986, 4,891 patents, or 0.9 percent of U.S. origin patents assigned to nongovernment organizations, were identified as having been assigned to universities [62]. The National Science Board report, *Science and Engineering Indicators—1987*, notes that the rate of increase in patents granted to U.S. universities and colleges between 1980 and 1985 "was more than double the rate of increase in the preceding 5 years; it was somewhat less, however, than the rate of increase for 1970–75" [35, p. 97]. For 1986, university-held patents represented 1.8 percent of total U.S. nongovernment patenting.

The revenue implications of this increase in academic patenting are as yet unclear. Omenn, highlighting some of the major university "winners"—Wisconsin's WARF, Indiana's share in stannous flouride patents—has observed that, "These examples demonstrate that the patenting and licensing route can be effective and, in extraordinary cases, lucrative" [43, p. 697). In addition to generating royalty income, and patenting and licensing programs, in Omenn's view they also "...support the university's objective of participating in the transfer of technology and make[s] the faculty member highly visible and therefore attractive for useful and remunerative consulting work within the bounds of university rules on time commitments" [43, p. 697]. [2] Although no systematic data are available on license and royalty streams for any large number of universities, statements of increasing university incomes may be found, with the (gross) amounts reportedly received in 1987–88 by Stanford ($9.1 million) [23], the University of California ($5.4 million), and the University of Wisconsin (about $5 million) heading the list [20].

These citations are seen as representing a new era of income streams. A buoyant statement from MIT's licensing office, for example, reports an increase in the number of patent applications filed in recent years from 100 to 150, and an increase in royalty income from $2 million in 1986 to $3.1 million in 1987. This increase, however, is only the beginning, with projections for revenues from royalties and equity holdings in firms created to commercialize MIT's patents totalling perhaps as much as $50 million over the next five years. Similarly, the University of Arkansas is projected as likely to receive "millions of dollars" by licensing its superconductivity discoveries [31].

Real as the stated figures may be, astute as university licensing offices may be, and tantalizing as future projects are, the income-generating aspects of increased commercialization activities for research universities as a whole are problematic. The historic examples of university success stories serve as much to illustrate the extremely long odds of attaining such outcomes as to support the substance of current projections. For example, the acknowledged pioneer among universities in the creation of an organizational vehicle that captures revenue from faculty inventions is, by general accounts, Wisconsin's Alumni Research Foundation (WARF). WARF, established as "a pioneer not-for-private-profit instrumentality" in 1925, had by 1985 distributed over $150 million in research grants and capital facilities to the University of Wisconsin, with its annual contribution rising to $8.5 million in 1985–86 [70]. Accounts of WARF's history repeatedly highlight the fact that its success has been based on a singular set of circumstances which would be difficult to replicate today [6]. WARF commenced operation in 1928 as the assignee of the Steenbock patent on Vitamin D irradiation, which quickly

[2] Omenn's review of the means used to take university research to the marketplace also highlights the reversal that has occurred since 1982, for he further writes: "To be sure, this approach (patenting and licensing) offers no return comparable to the sensational financial returns enjoyed by those who have benefited from the speculative fever of venture-capital investments and equity holdings during the past couple of years. However, it is increasingly apparent that that fever may have peaked and that the equity route is not a sure-fire route" [43, p. 697].

produced a sizeable royalty stream; it has had professional financial as well as research management, with 76 percent of its income through 1985 arising in the form of investment income.

For present purposes, the most interesting aspect of WARF's experience centers on the extremely low probability of faculty research leading to income-generating outcomes. Through 1985, WARF received 2,426 invention disclosures. From these came 448 patents, of which 203 (representing 95 inventions) were licensed. Of the licensed patents, 100 (representing 76 inventions) produced income greater than expenses: "Approximately a third of those 76 inventions have earned less than $10 thousand each, another third have produced between $10 and $100 thousand, and another third have earned in excess of $100 thousand. Total net income from patents, 1929–85, is more than $30 million, with 10 patents producing about 90% of that income" [70].

Moreover, recent university statements regarding their expectations from increased patenting and licensing initiatives emphasize revenue projections alone. Little information is available on the costs of securing patent rights (estimated to be between $5,000 to $10,000 for U.S. rights alone, with higher costs entailed for foreign rights) [36, p. 110], defending patent rights [68], and staffing and operating in-house technology-licensing offices. Moreover, the aggregate revenue estimates for any single university are based on "best case" assumptions of high and steady-state royalty streams for the duration of a patent for a large number of patents. They make no allowances for the ability of nonlicensees to develop alternative processes, albeit at a cost [25], and for potentially rapid decay rates of appropriable revenues from patent holdings in rapidly changing fields of technology [45]. [3]

[3] Although certainly not a controlling example, the experience of the Connecticut Product Development Corporation (CPDC), the longest-established state government venture to invest public funds in an effort to develop new products and create jobs, does serve at least to illustrate the risks and opportunity costs involved in the efforts of nonprofit organizations to generate revenue through R&D. Between 1972 and 1986, CPDC invested approximately $18 million in state funds. By 1986, it had entered into royalty agreements with 65 firms, involving 79 products, but over one-half of the investments had produced no royalties or royalties of less than 10 percent of the grant amount. The computed net return on public funds for the entire period was 1.3 percent [17].

Other than those found in a number of annual reports such as WARF provides, few data are currently available on the distribution of net income (or loss) among those universities that conduct their own patent and technology-licensing activities. The question of the profitability of university patent and licensing activities takes on increased importance due to the increasing number of members of the American Association of Universities (AAU) who have reduced or eliminated their use of patent management firms, such as the Research Corporation; established or expanded in-house technology transfer/licensing capabilities; and increased the number of professional employees.

Treating intellectual property rights as a profit center involves the following: (a) increases in the number of patent disclosures filed by faculty in response to changing federal legislation, university policies, and the climate of the time; (b) increases in fixed costs as universities develop the professional and technical staffs necessary to sift disclosures for subsequent filings, to file (and defend) applicants and patents, to negotiate licenses, and to actively seek out and negotiate with venture capitalists to create firms which will undertake further development and commercialization work on institutional patent holdings; (c) increases in variable costs associated with filing (and defending) patents; and (d) increases in the total number of licenses, with the distribution and form of payments a function of the characteristics of the patents and the strategies followed by technology-licensing offices [16]. Shaping university thinking in all of this are expectations of a skewed distribution of returns—that is, a large number of patents on which no or little income is received, and a few "block-busters" that cover the above increases in costs and yield substantial net revenues.

Given the few commercially profitable inventions emerging from those institutions representing the stellar successes, and the substantial minimum efficient scale of operation implicit in the above characterization of costs, there is a reasonably high probability that many universities that "invest" in expanded technology-licensing operations in order to produce substantial new sources of income will find themselves engaged in an economically chimerical pursuit and, indeed, may find themselves unable to recoup their direct expenditures. Bok's statement about the speculative nature of the financial advantages of aggres-

sive technology transfer programs to the university still holds.

But more is at stake than the return on micro-level investment decisions in this new willingness by universities to participate in the commercialization of faculty research. Profitable or not, an increased emphasis on patentable inventions and the commercialization of academic research cannot but affect its characteristics. At least three effects seem unavoidable given the economic logic driving these initiatives: (a) a shift in the supply of academic R&D directed towards questions whose answers constitute patentable outcomes; (b) a substitution by faculty of a more intensive involvement in post-discovery stages of research (licensability, commercialization) for work on new "scientific" questions; and (c) changes in the terms and means by which academic research flows to the market.

2.1. *Shift in the supply of academic R&D*

Academic research may be applied and have direct relevance to a well-defined industrial problem, as occurs when faculties have industrial support to study "proof-of-concept" questions such as: Are a particular set of performance characteristics technologically feasible? A different set of criteria determine satisfactory answers to academic and commercial questions. To be commercial, an innovative technique (product or process) must not only "work", but it must do so in a way that satisfies firm-specific profit criteria, which in turn rests upon demand and supply conditions relating to the innovation's cost–performance configurations and its placement in the market. What most serves to differentiate academic from industrial research is the willingness to take the steps necessary to fill the gaps between technological and commercial questions.

The disjuncture between and among the activities of academic research, academic patenting, and profitable innovation is evident in studies of the frequency and economic significance of patents flowing from NSF grants in chemistry and engineering. Marcy and Kosloski found that from 1964 to 1977, only 73 of 3,766 principal investigators (PIs) on chemistry grants were listed as named inventors. These PIs received a total of 95 patents that could be associated with NSF grants. Few were found to have economic value: they had limited commercial applicability, presented insurmountable difficulties in protection against infringement, and had no apparent economic advantage over existing processes [30]. A subsequent study of patents flowing from NSF's engineering program found that about 248 patents could be linked to 4,100 engineering grants; that most of these patents were without commercial value; and that of the 18 patents estimated to have commercial value, only 4 had generated royalty income [54]. The reasons advanced for the lack of commercial value are again straightforward: no market; prohibitive development costs; superseded; small market satisfied by simpler devices.

At issue, then, in considering university movement toward the commercialization of faculty research is not that such research to date has yielded so little in the way of patents, or that these patents, on average, have yielded so little in the way of commercial innovations. Rather, it is that to purposively attempt to change these outcomes requires an explicit change in the determination of academic research priorities. To be more patentable, and *a fortiori*, to be a licensable patent, requires that researchers incorporate an understanding of the competitive product environments of future vendors or customers when research questions are being initially formulated [18]. Reformulation of academic research agendas along such lines is now evident. A redirection of research priorities can be found in Blumenthal et al.'s study of university–industry relationships in biotechnology. Faculty members with industry support were more than four times as likely as faculty members without industry funds to report that their choice of research topics had been affected by the likelihood that the results would have commercial application [5]. This emphasis is being increasingly championed by university officials. [4]

Trade-offs occur in the shaping of research agendas between those research questions gener-

[4] Asked how the manifold increase in MIT's royalty revenues was to occur, John Preston, director of the technology license office, responded: "We've changed the professors' mentality... They've started thinking, 'If I can show commercial results, I'll have a better shot at raising my research funds.' They've changed away from pure scientific research" [20].

ated by the dynamics of scientific inquiry, and the economic logic of licensing arrangements. University-based patents to this point should be viewed as events generated by a set of institutions which sanction market-oriented behavior, but which extoll contributions to scientific fields of knowledge. Institutional endorsement of patent activity, and more strongly of the pursuit of research lines that have high(er) probabilities of generating appropriable income streams, changes the signals as to what constitutes productive allocation of faculty time.

2.2. *A more intensive involvement*

Institutional involvement in equity ventures designed to commercialize faculty research also affects the degree to which faculty members continue certain lines of research rather than move on to other subjects more highly esteemed by academic colleagues. The nature of the researcher's choice is highlighted by the juxtaposition of two statements: Ziman's observation that "Science evolves through innumerable particular decisions of individual scientists to undertake specific investigations" [71, p. 1]; and Schlicher's observation that the value and terms of licensing agreements relate to the degrees of technical and economic uncertainty surrounding advances in knowledge [55]. With universities having an increasing stake in the economic value of licenses, the institutional incentives to foster faculty research related to reducing technical and economic uncertainty increase as well, even when these lines of research diverge from "academic advances in knowledge".

The implications of this shaping of academic research priorities towards patentable questions are not fully evident. As noted in the opening section, a complementary link may indeed exist between the advance of science, applied as well as basic, and sharper market foci in the framing of research questions. Blumenthal et al.'s 1986 study indeed points in this direction as faculties engaged in biotechnology research with industry support were found to simultaneously publish at higher rates, patent more frequently and participate in more administration and professional activities than faculties without such support [5]. But what is also increasingly evident is that these initiatives are introducing new, market-oriented determinants into the positing of academic research questions; both directly and indirectly, they are inducing the loss of one of the few defining differences between academic and corporate research—the pursuit of the advancement of knowledge, largely unconstrained by prior filtering through prospects of commercializability.

The irony of this redirection, at least as suggested by historic performance to date, is that it may produce few successful commercializable outcomes. The fact that faculties are induced to shift their research agendas, to participate in spin-off firms, or to collaborate with limited partnerships, does not by any means guarantee that the commercial undertaking will be successful. It simply says that an increased number of faculties will be motivated or encouraged to make this effort. From this increased activity, given a "select" combination of academic scientists and fields of knowledge, undoubtedly will come some patents that yield patents streams, most likely of pioneering ventures, and some marketable products. That these gains will compensate for the loss of knowledge (and of purpose) as well as the redirection of faculty research is more problematic.

Moreover, this shift towards more potentially patentable research runs counter to other trends within academic research designed to correct the debilitating effects that a close identification with commercial needs have had on the quality of research. Historically, for example, it was MIT's shift away from industrially focused R&D agendas towards more scientifically oriented research that enabled it to simultaneously attain academic prominence and research dollars [55]. More contemporarily, state agricultural experiment stations have redefined their research agendas in order to elevate the importance of "contribution to the state of knowledge" relative to "client needs". This has been done to reinvigorate the scientific mettle of their research output (and also to negate proposals at the national level induced by assessments of the low scientific caliber of land-grant university agricultural research to shift federal funding from formula-based [Hatch Act] patterns to competitive grants) [15]. This reorientation has involved steps by experiment station directors to discourage researchers from working on industry-funded projects perceived to be of marginal scientific quality.

2.3. Changes in knowledge flows

Universities are treating two goals—tighter coupling of academic research, and commercial introduction in order to enhance U.S. international competitiveness and increased royalty incomes—as inherently compatible, whereas in fact they are not. University involvement in equity arrangements creates new market conduits through which academic research flows to the market. This involvement fosters "privatization of research", the distinguishing characteristic which, according to Nelson, serves to differentiate the private from the public aspect of technological knowledge [41] and which may compete with existing flows of knowledge.

Von Hippel, for example, has noted several examples in the field of scientific instruments in which university scientists, the "users", were responsible for the development of innovative techniques. They were then active in speeding the diffusion of their innovation, first because "(as required by the mores of science) innovating users (researchers) published their research results *and* the details of any homebuilt apparatus used to attain them. Second, they typically also informed others of their innovations by presentations at conferences and visits to the laboratories of other scientists" [66, p. 18]. This information was then rapidly assimilated by other scientists or by commercializing firms. Evidence of the flow and importance of academic research to technological innovation also is found in Mansfield's recent study in which 76 firms in 7 manufacturing industries reported that 11 percent of their new products and about 9 percent of their new processes commercialized between 1978 and 1981 could not have been developed (without substantial delay) in the absence of recent academic research [29].

The existing tracks upon which academic research flows to the market are likely to become blocked if not broken apart as universities limit existing flows of information in order to divert faculty findings to specific firms. At stake is far more than issues such as temporary delays in the publication of faculty research in order to give corporate sponsors an opportunity to file patent applications. Stallman has noted, for example, that

> "Traditionally, U.S. public breeders have discussed promising new varieties while still testing and have exchanged promising germ plasm at all stages of development. Both public and private sector breeders have commented that the public sector interest in patenting has limited this flow of information and germ plasm. All breeders express concern that this will retard the development of new knowledge" [57].

The result is likely to be lower rates of technological innovation.

Moreover, universities are not the only party to collaborative arrangements that are capable of changing patterns of behavior. Privatization by universities of the flow of academic research reduces the incentives that firms currently have to support R&D consortia and affiliates' programs. A key to the willingness of individual firms to support those university-based consortia addressing basic research or generic applied research questions, and publishing their findings in the open literature, is the firms' respective assessments that they are better able to internally assimilate and use this information than nonmembers [34].

The pursuit by universities of licensing initiatives through designated limited partners reduces the lead time subscribers to a university-based consortium have in the commercialization of scientific advances, and reduces their incentives to become members. Conversely, it provides them with increased incentives to develop new institutional arrangements for conducting generic research, such as industry-based consortia or contracts with for-profit R&D firms. It would be premature to project comparative revenue streams and rates of technology transfer from existing and new arrangements, but what certainly appears likely from these considerations is the high degree of substitutability among them.

3. Institutional change

U.S. public and private universities function in a constant state of flux, reflecting in good part their "openness" and "responsiveness" to national needs. Different perspectives of the missions of higher education—mental discipline, utility, re-

search, and liberal culture—have historically vied for primacy in shaping the content of the curricula, as well as the criteria to be used in faculty recruitment, promotion and tenure, and the organizational structures within which academic programs are conducted [65]. Almost reflexively, a national "crisis" requiring generation and utilization of knowledge leads public officials to turn to universities as an appropriate and effective source of assistance and/or causes universities to present themselves as repositories of requisite and relevant expertise.

Contemporary debates on the influence of economic signals on the direction of academic research have long-standing antecedents, as represented by the Taussig–Veblen contretemps. In this respect, recent initiatives for and by universities to take on expanded roles in fostering economic development form an unbroken lineage from Van Hise's "Wisconsin idea" of the early 1900s to Kerr's "multiuniversity" of the 1960s [22] to Lynton and Elman's recent call for basic changes in existing academic reward systems with a view towards placing as much value on interpretation and dissemination of new ideas as on original research [28].

However, there is an analytically soporific quality to employing such an historical recitation to legitimize increased university participation in the commercialization of faculty research: it proposes institutional changes of degree rather than kind; it suggests historic inexorability rather than identifying or assessing alternative possibilities in the face of proposals for new responsibilities; and it masks the mixed record of success that universities have had as they have assumed new social imperatives to conduct and transfer "relevant" research [14]. Moreover, and most importantly, it obscures those expansions in the range of services offered by universities, public and private, which have been provided mainly through developing and augmenting nonfaculty units, be these Department of Defense-funded research laboratories or industrial extension programs, and those which have affected or are likely to affect faculty allocation of time.

Universities are no longer seeking, as they were just a few years ago, to maintain a distance between what may be termed "core" and "peripheral" activities in the search to commercialize faculty research [3]. Proposals for universities to become aggressively involved in technological commercialization constitute change in that they affect the universities' "core" activities and norms, by directly affecting faculty research agendas. These changes entail far more than movements in the scale of operations (e.g. increases in industrial support of R&D or subscribers to affiliates programs) or the existence of specific programs (e.g. "interdisciplinary" energy policy centers funded by the Department of Energy), which constitute "normal" institutional perturbations (or fads).

Institutional change implies changes of a magnitude and duration that, over time, affect the qualities of individuals who seek a university affiliation (rather than an affiliation with an alternative institution), and affect personal assessments of the relative importance of intrinsic satisfaction on extrinsic rewards [33]. Institutional change entails socializing an organization's members to a new set of precepts, in part through a formal recasting of modes of compensation (salary) and status, but also through tacit but nevertheless widely understood (and shared) conclusions about those types of behaviors considered either appropriate or beyond the pale.

An abundance of (overlapping) theories of institutional change account for recent university actions to become directly involved in technological commercialization of academic research. Most embody variations on the following themes: increased awareness of the United States' international competition; changes in intellectual property rights; and increased financial opportunities which contribute to state economic development programs. Common to these themes is the degree of external pressures on universities: "The fate of academic science is in the hands of institutions outside the university, especially government" [50, p. 353] captures this mood. But external pressure is not a demonstrable reason for a university's pursuit of commercialization, nor for the dynamics now underway at Harvard or at those other, earlier universities. There is no evidence that those R&D-intensive firms that are the most direct users of academic research as well as the major sources of increased industrial support for the academic R&D that will maintain the "downstream" integration by universities of research and prototype development, have displayed little interest in this trend. To the contrary, industry has frequently stated its belief that universities are

being diverted from producing the type of knowledge valued by industry when they (universities) seek to directly develop specific products [10, pp. 90–91].

Scholars in the field of higher education have tended to explain recent university involvement in commercially oriented activities in terms of inter-organizational relationships. Dooris, for example, has argued that current trends reflect both "resource dependence" and "institutional isomorphism". Universities are adapting to fiscal stresses due to decreasing revenue streams caused by declining enrollments and fewer federal grants, by looking for "greater resources from business and industry—and have increasingly adopted the values of that community as well" [11]. [5]

To economists such as Davis and North, Harvard's action is a straightforward validation of economic theories of institutional change: "...economic institutions are innovated or property rights are revised because it appears desirable for individuals or groups to undertake the costs of such changes; they hope to capture some profit which is unattainable under the old arrangement. An institutional arrangement will be innovated if the expected gains exceed the expected costs" [8, p. 10].

It seems evident that a process of this type is at work. Institutional changes directed towards acceptance of an expanded university role in the commercialization of faculty research, as represented by Harvard's actions, appear to have been precipitated along the convergent lines already sketched by economists—a significant scientific role for academic researchers coupled with a venture capital market. Harvard's actions can be explained as an endeavor to retain as medical school faculty those researchers who may receive offers to enter private-sector employment. Not unexpectedly, Harvard's proposal is in the field of medical research, the patent class in which academic research is relatively most prominent. In this respect, a university's participation in limited partnerships is simply another means by which universities compete among themselves and with alternative employers for scarce resources: faculty engaged in state-of-the-art research [21, 50]. [6]

It is the intra- and inter-organizational diffusion of these institutional changes that is important. Changes in institutional policies, contractual arrangements, or internal norms cannot be limited to single colleges, departments, or disciplines. Universities may seek to act as "rational economic actors", making decisions at the margin, and indeed may be said to be doing so. Their decisions, however, affect core "institutional" standards and practices, not infinitely divisible resource flows. [7] The university dilutes its moral basis for limiting the involvement of these other faculties in like ventures once it participates in limited partnerships and like arrangements itself. Considerations of horizontal equity that provide all academic units with an equal opportunity to pursue commercial prospects even if these activities affect the selection of research questions or strain economic credulity; the asymmetrical fuzziness of revenue and cost projections which highlight "expected" gains, while leaving institutional costs obscured; the slow and at times difficult to discern pace at which the scientific quality of a faculty's research begins to slip; and the develop-

[5] A contrary view of this resource-dependence perspective is suggested by Dill, who notes that if a university's motivation for entering into R&D arrangements is scarce financial resources, an industry's motivation is scarce technical knowledge, moderated by a desire to limit risky investments. Industry is therefore likely to seek out research contracts with selected universities and scientists of acknowledged excellence, particularly since these contracts permit them to purchase these ideas at direct cost rather than the full-cost recovery necessary in their own R&D groups. Similarly, joint research ventures in marginal capital expenditures are likely to be appealing since they permit technical exploration without long-term financial commitment. In sum, the resource-dependence perspective suggests that universities and industry have quite different motivations for seeking out U/IRC, and that the shared desire to identify interdependent structures or forms which successfully promote innovation may be limited [9, p. 6].

[6] Similar sentiments can be found at other institutions. "Consortia are throwing us into research that is 'relevant' and basic as opposed to basic 'exploratory.' It means that a whole new group of potential faculty, that otherwise would have gone to industry, will stay on campus. Ten years ago they would have moved on" (Richard Cyert, President, Carnegie-Mellon University, as quoted in [10, p. 46]).

[7] Ruttan, for example, has couched his theory of induced institutional innovation, the means by which the research agendas of individual scientists are altered, on the single requirement that "there be an effective incentive mechanism to reward the scientists or administrators, by material benefits or prestige, for their contributions to the solution of problems that are of social or economic significance" [52, p. 33].

ment of an administrative cadre committed to expanding a university's commercialization activities, leave a university vulnerable to expanded, direct participation in such ventures. And, unlike the case of private-sector firms who, in Nelkin and Nelson's view, may make mistakes but have bottom-line profit strictures to "keep them from continuing to invest in activities that are not good for them" [39, p. 33], it is not readily apparent that universities will either recognize these situations when they confront them or be able to pull back on the extended commitments they have made. The efficiency snare of nonmarket organizations; the lack of market signals; the tendency to use too many resources relative to output or to seek to produce too much relative to foregone alternatives, may be latent in explaining the surge of universities into commercial arrangements [44]. Over time this lack may reveal itself in the slow rate at which institutions extricate themselves from financially unprofitable situations.

Institutional change among universities, however, is more than a process through which each single university computes its expected gains and costs. It also is a process of imitation and bandwagon effects as well [19], or of what academic sociologists are increasingly referring to as "mimetic isomorphism" [26]. It is in this respect that Harvard's actions are important, whereas comparable and earlier initiatives by the University of Utah, which has described its activities as "academic capitalism" [2, p. 12], were not. Harvard's policy reversal, given its standing as a premiere research institution, and the articulateness with which its president had previously sought to set university participation in commercial undertakings, serves to increase the pressure on like institutions to establish comparable policies in order to retain otherwise mobile faculties. Moreover, the reputational penumbra cast by Harvard's actions makes it more difficult for other universities to resist proposals to participate in equity ventures on the basis of their impacts upon the university's missions or its vague economic underpinnings.

4. Conclusion

Participation in ventures that will commercialize faculty research may be explained as necessary adjustments to retain resources (faculty) being lured by competing bidders and by optimistic projections generated by examples of "winners", either home-grown or from comparable institutions. However, policies influenced in the short run by efforts towards the best and the brightest, or most patentable and profitable of university-based research endeavors affect the larger set of signals, incentives, and norms for other researchers, and thus in the long run, affect all forms of academic knowledge.

There is little reason to expect, based on past performance, that any sizeable reallocation of faculty efforts towards commercially oriented R&D will generate appreciable new net revenues for other than a select number of universities. Seeking to garner sizeable net revenue streams from increased patent and technology licensing is for most institutions the equivalent of purchasing lottery tickets whose expected value is likely to be less than the purchase price.

Increased patent/technology licensing operations may simply be a money-losing proposition, as royalty and licensing incomes fall short of the "full" costs of operating these programs. Factored into these revenue calculations also must be the likely substitution of revenue streams as current industrial sponsors draw back from funding research whose findings may be channelled to competing enterprises.

Increased efforts by universities to foster the commercialization of technological innovations erode the singular position occupied by institutions of higher learning in the United States. Universities have accumulated intellectual and political capital not only because of their scientific and technical expertise, but because of their symbolic and putative role as an engaged but monetarily disinterested participant in social discourse. Universities, by mission and popular acceptance, are societal institutions whose individual members are available to serve as "neutral" sources of expertise.

A disinterested, nonpecuniary orientation serves as the foundation for the faculty members' ability to venture forth from the ivory tower to contribute in a wide variety of expert, policy, advisory, or litigious settings. As Bok has noted, "The introduction of a different set of motives oriented towards private gain threatens to reduce the credibility of the scientists involved and to diminish the

capacity either to elicit complete trust from their colleagues or to secure the unmixed admiration of the public" [7, p. 151].

"Thinking one can" may be a sign of creative and financially astute entrepreneurship on the part of universities. But whether profitable or not, these ventures serve to shift academic researchers from the social roles in which they are most efficient, as suppliers of a collective good—scientific and technological knowledge.

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