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Universities, technology transfer, and industrial R&D

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ABSTRACT:

Some of the most important innovations to emerge in recent years—which have transformed whole industries, particularly in the areas of biotechnology (transforming medicine and agriculture) and information technology (transforming computing and communications)—were the result of research conducted in universities and public sector institutions. Many of these institutions have recently established Offices of Technology Transfer (OTTs) that aim to manage their intellectual property and to commercialize some of their research products. Technology transfer has meant more than just the licensing of patents: substantial numbers of university researchers have migrated to private industry, establishing start-up companies. This paper provides a perspective on the economic forces at work in the transfer of technology from publicly funded research to commercial use. It provides an overview of the differences and the relationships between public and private research and then introduces, interprets, and analyzes results from several recent surveys of OTT operations and results. Finally, it draws implications for public policymakers, university administrators, and company managers.

JEL CLASSIFICATIONS:
H42—Publicly Provided Private Goods; L33—Boundaries of Public and Private Enterprise, Privatization, Contracting Out; M0—General Business Administration and Business Economics; O31—Innovation and Invention: Processes and Incentives; O32—Management of Technological Innovation and R&D

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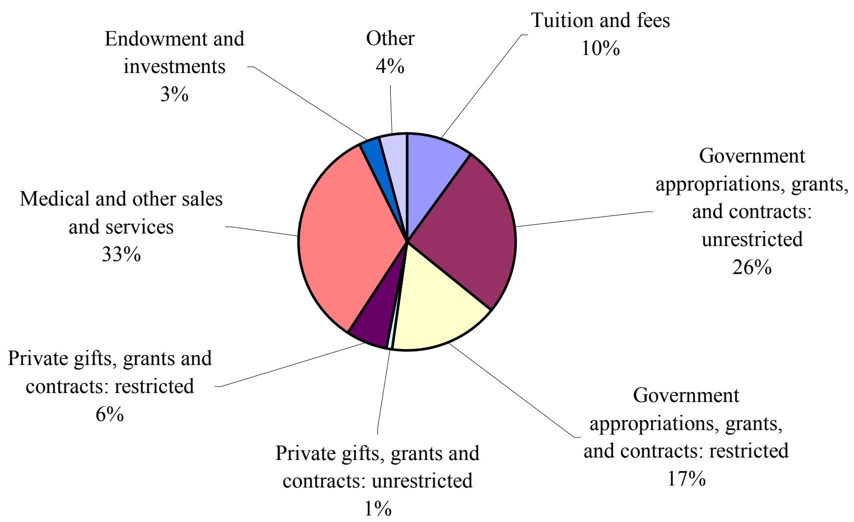
1. The University Enterprise and the "Educational-Industrial Complex"

The 21st century American university is an institution that has evolved to meet multiple objectives. Universities are expected to educate their student-customers, contribute works of culture, nurture the arts, host the intellectual conscience and discourse of society, and generate new scientific knowledge for the good of both the economy and society at large. These various outputs consist—in the parlance of economics—of both *public* and *private* goods. For example, through educational services universities provide individuals with skills that increase their private earning potential, generates human capital for firms to hire and to utilize, and, in general, makes for a more educated and cultured citizenry. Through laboratory research universities aim both to solve specific problems—thereby building specific intellectual capital that can be intentionally used by firms—and to create generalized, abstract forms of knowledge that are impossible to quantify or contain.

This multiplicity of objectives leads the university to draw upon a wide variety of funding sources to support its activities. General university revenues come from tuition and fees, from federal, state, and local government grants and budget allocations (particularly for public universities), from endowment and investment income, and from private gifts and grants from industry, benefactors, and foundations. In addition, individual programs and research projects conducted at universities are supported by restricted (i.e. program designated) grants applied for and recieved from government and private sources. Figure 1 illustrates the variety of revenue sources of for one the largest public university in the U.S., the ten campus system of the University of California. The pursuit of multiple objectives and the concommitant reliance on a variety of funding sources enable universities, when it comes to conducting scientific research, to establish research units that are quite unique in their capabilities and that have distinct relative advantages in terms of capacity and cost effectiveness in pursing certain kinds of research.

Taken together, this set of objectives of the 21st century American university system and its economy-wide coalition of beneficiaries and benefactors make up what may be regarded as today's '*educational-industrial complex*.' This social-and-economic infrastructure may not be as menacing to many as that which supported the Cold War, but it similarly constitutes much of the very fabric of contemporary life and business that knits together the knowledge-based economy. The key element of the equation that has tipped the American research university from being 'provider of standardized educational services and public goods' to becoming 'key component in the national economic infrastructure' is the economic power wrought occasionally but repeatedly by new technologies that emerge from university research and move out into commerce, leading to the development of new products and processes. University research results have led to the creation of whole new firms and even industries, brought old ones down, and, in general, profoundly impacted rates of industrial innovation. University research is a source of competativeness, effectively serving an anti-trust role when new technologies like young Davids rise up to challenge the technological base of oligopolistic Goliaths in established markets. For existing firms, the univeristy can be both a problem and a solution, a technological competator and a technological savior: and the entire difference turns on relationships formed and intellectual property rights won in an arcane sounding process known as ‘*technology transfer*.’

Figure 1. ***Who pays the piper? The variety of funding sources for the University of California system in 2000.***



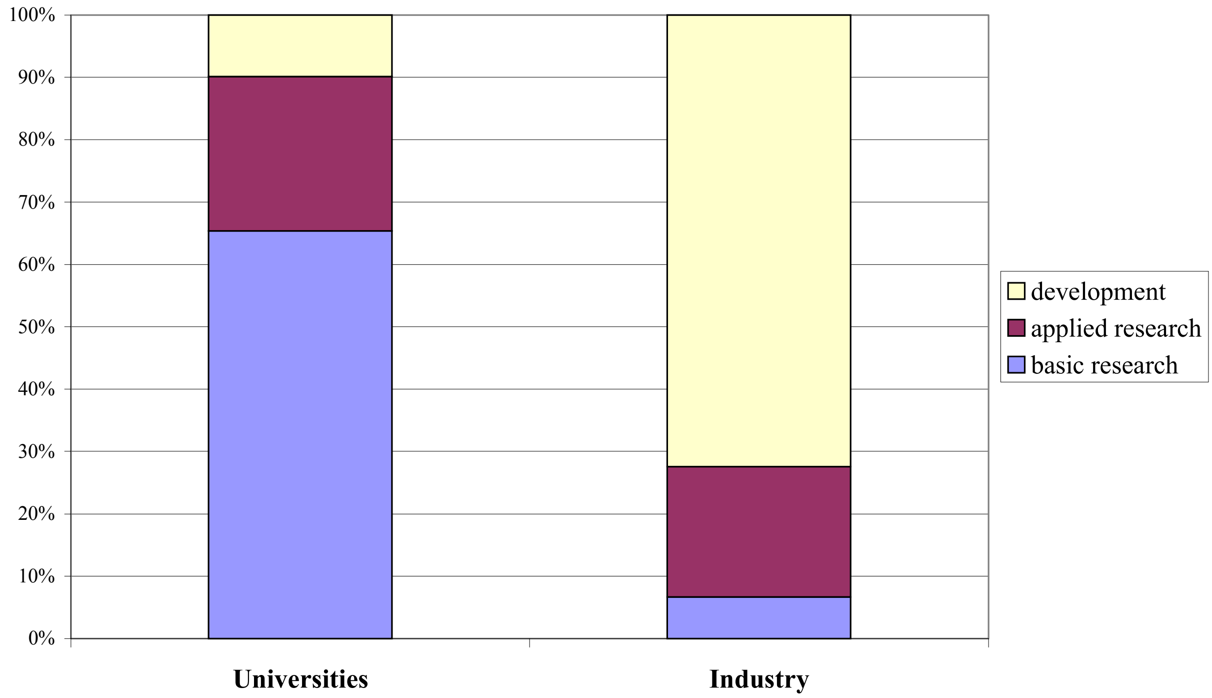
Source: The University of California, Annual Financial Report 1999-2000

2. Is *basic* research necessarily *public* or *academic* research?

Since at least the 1940s a conventional distinction has been drawn between *basic* research and *applied* research. This distinction is enshrined in the annual national R&D statistics reported by the National Science Foundation (NSF), for whom ‘basic’ research is defined as that primarily intended “to gain more comprehensive knowledge or understanding of the subject under study, without specific applications in mind” (National Science Board, 2000). Basic research is, economically speaking, assumed to have stronger *public goods* properties: to yield general knowledge and to generate benefits that are difficult for individual parties to appropriate as rents or as commercial profits. Thus, basic research has conventionally been assumed to be the province of universities while industry is left to concentrate where its interests and expertise lie, in applied research and development[5]. The prevailing paradigm holds that a mutually beneficial division of labor exists between the universities and industry. This division of labor is illustrated in Figure 2 by the NSF categorizations of the character of the R&D undertaken in U.S. universities and U.S. industry in 1998.

These NSF figues show that—in 1998—69 percent of the R&D undertaken at academic institutions was characterized as 'basic' research. Of course, the proportion of basic R&D is higher or lower than this in the different fields and departments across academia. Overall, however, it is arguably the primary focus of universitiy science: the academic sector is the single largest performer of basic research in the U.S. Yet still, 24 percent of university research falls in the 'applied' category and 7 percent is considered 'development' work (National Science Board, 2000, see Figure 1).

Figure 2. ***The division of labor: categories of R&D conducted in U.S. universities and industry in 1998.***



Source: National Science Board, 2000.

[5] We will follow NSF convention and use the term 'R&D' to refer to all of these categories collectively, unless otherwise specified (see National Science Board, 2000).

Rosenberg and Nelson (1994) challenge the convention of a black and white distinction between basic and applied research, particularly when it comes to describing the research undertaken at universities. They argue that in the United States, especially following World War II, much of the publicly funded university research was in fact targeted at solving practical, concrete problems. The lion's share of public research funding, they point out, was funneled through the Department of Defense (DOD), the Department of Energy (DOE), the National Institute of Health (NIH), and the Department of Agriculture (USDA), each with a general mandate to solve a specific class of problems faced by society at large. Even research projects supported by the NSF—an organization traditionally dedicated to basic science—have strong problem-solving orientations. Universities in America were among the first in the world to introduce industry-targeted scientific disciplines such as chemical engineering and computer science, aimed to provide solutions and to train scientists for industry's newly emerging problem areas. While basic research may concentrate on providing the fundamental knowledge and systematic methodologies of the scientific disciplines, it is ultimately justified as leading to the solutions of the practical problems facing government, industry, and society at large.

This approach advocated by Rosenberg and Nelson views research projects as lying somewhere on a continuum streaching between the extremes of 'basic' and 'applied'— with particular pieces of research often encompassing both abstracts fundamental issues of human knowledge and targeted solutions to specific, concrete problems. While universities emphasize work that is in some respects closer to the 'basic' end of this continuum, their efforts are nevertheless intended to result in practical knowledge and technologies, which can and do lead to commercially viable inventions.

There are several fundamental reasons for which economists argue that public funds should be expended to support basic research, even despite its pragmatic and sometimes commercially profitable outcomes. The classic economic analysis maintains that basic research is far too uncertain and its return horizon too long to be left to private sector enterprises that need to meet Wall Street standards. Betting on the outcome of individual basic reaserch projects is risky, so much so in fact that, left to their own criteria, individual private companies simply cannot on their own invest nearly enough to supply the full gammut of basic research that society, and even they themselves would need. Thus, basic research that is deemed valuable in broad social terms or in medium to long run economic terms must be funded by the pubic sector if it is to be done at all. The underlying economic reasons are, succinctly, as follows:

1. ***Uncertainty***: The outcome of basic research is highly uncertain, and society as a whole is assumed to be less averse to shouldering the risk involved in the cost-benefit tradeoff of basic research than are individual firms.
2. ***Inappropriability or 'non-marketability'***: Some results from basic research, while valuable, are simply not appropriable, because they occur at such fundamental levels of scientific analysis. For example, the discovery of the double-helix structure of DNA was not patentable, nor could any product be made directly from that particular insight alone. However, Watson and Crick won the Nobel Prize for this contribution, and the entire biotechnology industry owes it existence, in part, to that fundamental knowledge.
3. ***Spillovers***: Some results from basic research, while valuable, can spill over to competitors in the same line of business (that is, they can be learned and adopted by those competitors) so easily that the results may actually help the competitors more than they help the company that did the initial research.
4. ***General purpose***: Results from basic research are often able to improve multiple lines of business, but individual private companies employ specialized assets and business methods to create, manufacture, and market specific lines of products. They do not have a competitive advantage in the utilization of an innovation in lines of business where they are not already active, which means their expected return on investing in basic research is lower than the expected returns in the the economy as a whole. Thus, instead, most individual private companies conduct research that aims to improve their own product lines, to overcome quality or production problems, and to expand their offerings within their area of specialization.
5. ***Competence destroying***: Occasionally, a *radical* innovation arises from basic research that renders the old way of doing business altogether obsolete. The tide let loose by such an innovation can be powerful and unpredictable enough that even industrial giants are challenged, become less cost effective than new competitors, and lose market share. Technologically adept incumbent firms will eventually find that they have to maneuver to adopt such a radical innovation as it spreads and becomes standardized, but such established firms it is argued—despite the rhetoric of some of the more R&D savvy—do not face sufficient incentives to pursue the research that might lead to such radical innovation and thus undermine their existing market base (Henderson, 1993). There are no theoretical guarantees and scarce real-world precedent that the creators of radical innovations are able to control the new technology for long or to realize a net profit from its use.

6. ***Indivisibilities and specificities***: And, finally, some basic research requires large dedicated investment in unique equipment and highly specialized skills of individual scientists.

3. Observing the dynamic nature of the innovation process: technological trajectories

Inventions of industrial importance are rarely one-off occurances, regardless of where they originate. Instead, the innovation process typically involves quite a number of steps carried out over time, with each step leading to the next. The so-called 'linear hypothesis' of the relationship between basic science and applied technology claims the following: since, by definition, basic R&D preceeds and enables applied R&D, the work at institutions specializing in basic R&D, largely universities, necessarily preceeds and makes possible the work at institutions specializing in applied R&D, largely companies in the private sector.

There has been frustration, however, in trying to empirically demonstrate such a simple dichotomous causal relationship between public and private R&D work. In other work Rosenberg (1994) points to the bi-directional flow of knowledge between high-powered corporate research labs and universities, on what he calls the 'two-way street' of technology exchange. In pharmaceuticals Cockburn and Henderson (1996) examine the immediate flow of knowledge between public and private researchers in a bibliometric-type analysis of coauthorship of research papers. They find a significant amount of coauthorship between public and private researchers and take that to imply that the "simple linear model of the relationship between public and private research" is "misleading". In agricultural research Huffman (1998) dismisses a direct one-way relationship between basic and applied work, citing the long history of practical problem solving on the farm driving the agenda for basic research at public land-grant universities.

Much of the literature in markting emphasises the importance of listening to customers as a source of new product innovation and product improvement ideas, and indeed, innovations can be the result of feedback from clients or from those marketing personnel who sell or service the product. Even in these cases, however, once the idea is introduced within a firm and committed to, a rather linear process of research, development, production, and marketing will follow. A consensus holds that there is some kind of systematic and mutually beneficial cause and effect relationship between university research and industry R&D, but not one that is simple, nor necessarily linear.

More realistic views of the growth patterns followed by new technologies can be found in a general set of theories that describe whole families of new technological solutions being birthed by specific breakthrough discoveries that provide the technological or conceptual tools which allow companies both to focus on solving problems in their production technology (conducting supply-driven or 'technology-pushed' applied R&D) and to focus on meeting the demands of their customers in new ways (through demand-driven or 'demand-pulled' applied R&D). In a review of empirical economic studies of innovation, Cohen and Levin (1989) describe several economists' views of the interactions between basic and applied R&D along this kind of a causal sequence that evolves over time:

1. ***Creation of technological opportunity***: A basic invention decreases the cost of seeking solutions to a practical problem, thus making the process of applied research more efficient by limiting the number of possibilities over which to search (Rosenberg, 1974; Evenson and Kislev, 1976; Nelson, 1982).
2. ***Compulsive sequences***: A breakthrough in one area generates new problems or imbalances in the production system that require innovations in other areas (Rosenberg, 1969).
3. ***Technology life cycles***: The nature of innovation changes in a predictable manner over the life span of its industrial application, beginning with a 'radical' innovation, proceeding through a phase of experimental 'product' innovations, and followed by a competitive phase of 'process' innovations as the industrial application becomes commodified (Abernathy and Utterback, 1978; Utterback, 1979).
4. ***Technological paradigms and natural trajectories***: Technologies have a tendency to develop along a relatively clear path by repeatedly focusing on a particular class of problems or using a particular breakthrough discovery as a starting point. A cluster of closely related innovations form within a particular problem solving paradigm and it evolves with further research along a specific technological trajectory through time (Nelson and Winter, 1977; Sahal, 1981; Dosi, 1982; Dosi, 1988).

The linear hypothesis, recast in terms of technological trajectories, describes basic research as the process of actively brainstorming and exploring the variety of possible problem solving paradigms in a given field of human inquiry or technology. Several new technological paradigms might emerge from such basic work in a given field, but each is tested under the scrutiny of peer-reviewed science, the rigors of regulatory criteria, the selective forces of the technology marketplace, and the popular voice of social acceptance or rejection. Occasionally, follow-on innovations, inspired by and clustering within the parameters defined by a successful new paradigm begin to take off, growing over time into a 'branch' on the technological 'family tree'. In the early 'basic' phases of such a natural trajectory, there is still much uncertainty about what direction the technology will take and whether it will be of any commercial value. Understandably, before profitable application has been reasonably proven, only those willing to shoulder a fair amount of investment risk or those who have a deep understanding or clear vision of the technology's potential can be found to financially back its further development. However, once the technology is proven, industry can be expected to become very interested in the technology and a broader set of investors can be found to back the incremental innovations necessary to adapt the technology to particular industrial products and processes, thus driving the growth of the trajectory through its middle and later 'applied' phases.

4. The incentives and constraints that shape university research

To really understand the differences between research in universities and private industry, one must compare the objectives and incentives faced by individual scientists located in both types of institution: 'the university' and 'the company'. The general objectives of virtually every scientist in the world can be summed up as the pursuit of (some combination of) the three 'F's—*fame*, *fortune*, and *freedom*. What we mean by 'fame' and 'fortune' should be quite obvious; what we mean by 'freedom' is *self-determination*: a researcher's ability to select his or her own research objectives and strategies, the ability to "be ones own boss." However, constraints faced by researchers in the university and in industry differ significantly, resulting in different patterns of behavior on the parts of individual researchers. At the end of the day, the collective effects of individual researchers' decisions made under the different systems of incentives and constraints determine the innovative results of the different sectors.

At universities the three objectives of scientists are complementary. Academic fame generally results in individual fortune, in terms of higher salary, more lucrative opportunities for consulting, and the like. Fame also gives rise to freedom. A well regarded professor can generate more research funding and gain better access to research equipment and facilities, which in turn results in greater freedom to choose the path of research.

Furthermore, at universities the objectives of research are at least broadly complementary to the other basic objectives of the university enterprise. Research that leads to innovations also helps to educate students and enhances the researcher's knowledge beyond the scope of previous training or research projects.

The output of university researchers is typically embodied in the publication of scientific papers and books, in the training of graduate students with knowledge and skills that they will carry on with them, and in the awarding of patents and other forms of intellectual property. Particularly for peer-reviewed, scholarly publications, the most important criteria by which success is judged are the significance of the problem and the originality and creativity of the solution posed. This pair of criteria—originality and creativity—drive university scientists to differentiate and diversify their projects, their careers, and themselves, ultimately creating a broad portfolio of problem solving paradigms and specific innovations, most of which may be merely "interesting" to the layperson observing from outside the given scientific field and most of which may not be at all practical or cost effective for a profit-seeking enterprise. However, occasionally—as this perspective suggests—the relentless drive at universities for diverse, creative research results in important breakthrough discoveries.

5. The incentives and constraints that shape industry R&D

In most cases, researchers working in industry are subject to a somewhat different set of constraints, which arise mainly from the need to show short term profability. While some research centers in industry operate like universities—as is the case with Bell Labs or Xerox PARC—these are the exception rather than the rule: most industry research efforts are quite targeted, and scientists in industry tend to have have less freedom than those in academia. Weight is given to research that is expected to contribute directly to the firm's ability to create value by increasing revenues or reducing costs.

Much of the research and the development work in industry is managed sequentially, in phases leading up to the introduction of new production processes or new products. Millions of R&D dollars are spent, for example, on routinely pre-testing drugs, chemicals, and other such products for regulatory approval. In making investments of this magnitude, private firms spend primarily on the improvement of specific proprietary industrial processes or products that are owned or licensed by the company and that are very certain to yield a positive rate of return within a reasonable time horizon, such as the term of a patent.

6. Research specialization and the division of labor between universities and industry

As a result of these differences, one expects university research to result more often in ideas and methodologies (radical innovations) that are original and differentiated from existing processes and products already found in industry, while research within industry is more likely to result in (incremental) innovations that are derived from and improve upon existing products and processes. Since much of the reward in academic circles is given to new ideas and creative concepts, with less attention for their ultimate implementation, research products of universities that do promise eventual commercial application tend to provide only a starting point that requires significant amounts of follow-on innovation, further development, and refinement.

Such research results in the university can be patentable, even when the potential of their commercial application is subject to much uncertainty. In their embryonic stage university research products may not be interesting or promising to the established firms in an industry, especially when the research does not appear to have links to the firms' existing production processes, product lines, or strategic plans. This suggests that some research products need first to pass through an incubation phase that will continue their development in directions that lead closer to the demand side.

Investors specializing in high-risk, high-return opportunities may be interested in developing some of the university's more promising research products. Indeed, a large number of start-up companies in information technology, biotechnology, and other fields have been established through alliances of researchers, venture capitalists, and entrepreneurial business managers and salespeople, expressly to take a new innovation from its initial stage closer to a final product. Often these start-ups are then absorbed within large corporations who rely on the start-ups to complement their own research labs. For example, Cetus was purchased by Hoffmann-LaRoche, while Calgene was taken over by Monsanto. The major corporations have a much stronger apparatus for product testing, as well as marketing and production. These corporations rely on start ups to complement their research labs and other capabilities, and in turn start ups rely on univerity reasearch. These patterns of development, especially as manifested in biotechnology and information technology, thus suggest complementarily between corporate and university research.

The process of innovating and introducing new products can for most cases be generalized and simplified into a few basic stages. These include research, development, production, and marketing. We consolidate the organizations involved in this process into three major categories according to our discussion: universities (U), entrepreneurial start-up companies (S), and established corporations (C). Table 1 presents patterns of the division of responsibility among these three kinds of organizations.

1. In some cases, all the innovation activities occur within a single established corporation (Pattern 1 in Table 1.)
2. In other cases, university researchers come up with an initial discovery and license or sell it directly to an existing corporation (Pattern 2).
3. In another set of cases university researchers develop an idea, sell it to a start-up, or obtain financing from venture capitalists to spin it out as a start-up company. Then the start-up company commercializes and markets products based on the new innovation [6] (Pattern 3.)
4. A variant of pattern 3 occurs when the startup company is taken over by an existing major corporation which then commercializes and markets products based on the original university innovation (Pattern 4.)
5. In a more rare variant of pattern 3, university researchers come up with an idea, sell it or spin it out to a start-up company, which itself then grows to become a major corporation based on the new technology (Pattern 5.) Examples include Genentech and Chiron.
6. The process of technology transfer is not limited to universities. A fairly recent phenomenon has been a surge in out-licensing of intellectual property by companies, and it has become an serious source of earnings for corporations with strong research capacities. For example, IBM earned close to $1 billion in 1998 from royalties that are largely outcomes of its own in-house research (Valery, 1999). In some of those cases of corporate out-licensing, such as at Lucent, practitioners or researchers within the company may come up with an idea that does not fit closely within the firm's core specialization; they are encouraged to refine it, obtain financing from venture capital or other such sources, and start their own firm to commercialize the idea separately from the parent company (Buderi, 2000) (Pattern 6.) It is not a brand new idea, however; Sony, for example, was founded by a Masaru Ibuka and Akio Morita when they obtained rights to the transistor by licensing patents from Bell Laboratories (Morita, 1988).
7. Finally, it has also been recently observed that, on occasion when company researchers have created patented technologies that do not fit closely enough with the firm's core business, the company will donate the patents to a university to further refine and manage its commercialization (Pattern 7.) This can result in a significant tax write off for the donor firm.

[6] It should be clear that technology transfers go well beyond the simple licensing of intellectual property. In fact, often, university professors and ex-graduate students may start new companies without any formal transfer of intellectual property rights.

Table 1. ***Common patterns of the division of labor of the innovation process***

Pattern	Research	Development	Production	Marketing
1	**C**	**C**	**C**	**C**
2	**U**	**C**	**C**	**C**
3	**U**	**S**	**S**	**S**
4	**U**	**S**	**C+S**	**C+S**
5	**U**	**S**	**C=S**	**C=S**
6	**C**	**S**	(then any of 3-5…)	
7	**C→U**	(then any of 2-5…)		

Where* U = *universities,* S = *start-up companies,* C = *corporations

University *offices of technology transfer* (OTTs) are especially important in providing the link between university inventors and existing companies (in Pattern 2) as well as between university inventors and investors in new start up ventures (in Patterns 3 - 5). In the next section we discuss how OTTs are organized and how they perform in meeting these goals.

7. University Offices of Technology Transfer: Objectives, Challenges, and Operations

Offices of technology transfer (OTTs) were established to facilitate the development and utilization of commercially viable innovations discovered by university and government scientists. The Research Corporation, founded in 1912 by a University of California-Berkeley faculty member to sell rights to use patents of several affiliated universities, was a predecessor to the contemporary OTT (Mowery et al., 2001). Several leading research universities, including the University of California, Stanford, MIT, and the University of Wisconsin, established their OTTs over 30 years ago. However, it was the passage of the Bayh-Dole Act in 1980 that catalyzed the development of technology transfer programs at most institutions. This Act of Congress created a uniform patenting policy among all the federal agencies that fund research, which allows research institutions to retain intellectual property title to the material and products invented by their employees doing research under federal funding. A survey of 106 university and government research laboratory OTTs conducted by several of the current authors (Castillo et al., 2000) found that 78 percent of the OTTs surveyed were created after the passage of the Bayh-Dole Act. Overall, the Association of University Technology Managers (AUTM) reports that in 1980 only 25 offices existed, but a decade later, by 1990, 200 such offices existed (reported in Mowery et al., 2001).

7.a *OTTs are subject to faculty, administration, and state priorities*

The initial impetus for establishing OTTs, even prior to the Bayh-Dole Act, was the concern by faculty and administrators that many of their most promising ideas were not being sufficiently utilized by the private sector. Universities came to recognize that private firms would not be interested in developing university-spawned technologies unless they could obtain (often exclusive) rights to them. Two other objectives of OTTs have grown more prominent over time: the provision of legal and intellectual property management services to university researchers and the collection of licensing royalty revenues for the university. When university researchers wish to commercialize their ideas, OTTs provide a formal, above the board, and relatively effective mechanism. The revenues generated by OTT licensing, while still only a minor percentage of universities' operating budgets, have grown substantially. Beyond their monetary value the growth of such royalty revenues serves to demonstrate the success of OTTs in diffusing the fruit of the university's research.

In a study undertaken to review the economic effects of the Bayh-Dole Act, Jensen and Thursby (2001) surveyed sixty-two research universities concerning their technology transfer activities for the years 1991-1995. Questions were asked of the technology transfer offices, the faculty, and the administrations about their objectives for technology transfer. The different parties' responses demonstrate that the differences that exist within the university over technology transfer. Administrators tend to consider technology-associated revenues most important, while the faculty see the ability to attract research sponsorship as paramount (Table 2). OTTs often operate under somewhat conflicting mandates from their administration and faculty and emphasize the more immediate and tangible outcomes of executed licenses and commercialized inventions.

Table 2. ***Divergent priorities: ranking the importance of university technology transfer outcomes by OTT officers, administrators, and faculty***

Outcome	Technology transfer officers' priority ranking	University administrations' priority ranking	University faculty members' priority ranking
Revenue	1	1	2
Inventions commercialized	2	3	3
Licenses executed	3	4	5
Sponsored research	4	2	1
Patents granted	5	5	4

Source: Jensen and Thursby, 2001

Beyond what the various parties report to be priorities for technology transfer, actual investments of time by OTT staff in particular activities reveal how OTT staff respond to (and perhaps balance) the conflicting demands placed on them (Castillo et al., 2000). OTT officials undertake multiple tasks: they scout and assess inventions at their institutions, make patent applications, market patent rights to possible buyers, mediate contacts between their institution's personnel and outside investors, and monitor and enforce licensing and research contracts. The time spent on a successful invention by an OTT is typically split 50-50 between efforts expended prior to and efforts expended after patenting. Pre-patenting activities involve solicitation of invention disclosures from faculty, evaluation of inventions, and assessment of their economic potential. Patent preparation involves, on average, only about ten percent of the total time and efforts of OTT staff [7]. Commercialization efforts, including the negotiation of a license, involve about 25 to 30 percent, and follow-up activities of monitoring and enforcement involve only about ten percent of an OTTs expended time. (See Table 3 below.)

Prior to the mid-90s private universities appeared to put more effort than public universities into securing earnings from technology transfer. Private universities emphasized market related activities (evaluating inventions and assessing markets) and spent relatively more time enforcing and monitoring contracts [8].

Table 3. ***Revealed priorities: percentage of time on the job that public and private university OTT officers spent on various activities in 1999***

Activity	Public universities (percent time)	Private universities (percent time)	Both (percent time)
Soliciting ideas	11.3	7.8	10.0
Evaluating inventions	14.1	16.6	15.0
Assessing markets	12.5	13.6	12.9
Referring inventors	3.8	2.4	3.3
Preparing patent applications	8.6	10.1	9.1
Drafting licenses	24.3	24.6	24.4
Enforcing patents	2.8	5.0	3.6
Monitoring contracts	7.2	11.5	8.7

[7] This figure is in accordance with the relatively low priority given to patenting by all of the parties in the university in the Jensen and Thursby survey (see Table 2.)
[8] Spending more time on monitoring contracts also increases contact time with clients and builds and enhances the social networking that may lead to future transfers.

Other	15.8	10.1	13.9

Source: Castillo, Parker, and Zilberman, 2000

7.b OTT decisions of what to patent, and when

One of the greatest challenges faced by offices of technology transfer is identifying and separating out commercially promising ideas from among the large volumes of publicly oriented knowledge constantly being created at the university. The probability that an OTT will patent a certain innovation is greater if

- a technology is clearly patentable,
- a technology has favorable cost-benefit considerations (good commercial prospects or a potential buyer is already interested in the technology),
- a potential buyer offers to patent collaboratively, or
- the OTT is approached and even pressured by a faculty inventor.

If none of these conditions are met, the OTT may chose not to pattent the invention but rather to give the the faculty inventor the right to utilize and pursue it. Some faculty have used unpatented technology to start firms {actual examples?}.

In survey interviews, most OTT officials agree that, despite the importance of revenue earnings from technology transfer, in the decision of when to patent, financial concerns do not dominate academic considerations. While a short delay in publication may be imposed for the practical purpose of allowing a priority date to a patent application, faculty members are permitted and encouraged to publish the results and to compete in the academic research race (Postlewait et al., 1993).

7.c Allocation of revenues within the university

There are a variety of different formulas used as university policies for the allocation of OTT revenues from license royalties. The most common formula is equal sharing among the university (33%), the department (33%), and the employee inventor (33%), while another commonly reported alternative is a 50%-50% sharing between the university and the inventor (Castillo et al., 2000). Jensen and Thursby (2001) report average net revenue distributions going to university (35%), department (25%), and faculty inventor (40%). When a department shares in the royalties it is often justified as taking into account the research and collaboration efforts of the entire team that led to an invention or indirectly helped to make it possible. In this way the whole organization that contributed to the success, and not just the principal researcher, benefits from the proceeds. However, patterns of royalty sharing that dilute the inventor's share may increase their incentive to depart from the university.

8. Measuring the performance and results of Offices of Technology Transfer

The results of OTT activities can be measured in several dimensions. OTTs issue patents and licenses, help establish start-up companies, and collect revenues in the forms of signing fees, royalties, penalties, and equity in start-up companies. OTT activities also result directly or indirectly in research contracts, grants, and donations to the university.

8.a University technology licensing revenues: cash and equity

Figures 3.a and 3.b show the distribution of technology licensing revenues for the top 30 universities in 1992 and in 1995 out of a sample of 106 institutions compiled from AUTM data by our Castillo, Parker, and Zilberman survey. [9] In 1992, six of the institutions were big hitters, with total earnings each between $10 million and $30 million. In 1995, the top three universities had each exceeded $30 million in earnings with an additional four universities bringing in around $10 million. The overall earnings for the top 30 in 1995 was up roughly 80 percent from the overall earnings for the top 30 in 1992. [10] This may reflect royalties from new patents, higher royalties generated by products resulting from existing university patents, and more aggressive commercialization on the part of the OTT in general. There were two turnovers in the top ten from 1992 to 1995, and eight turnovers in the top thirty.

Table 4 presents the results of the authors' survey regarding preferences among OTTs for compensation in cash or in equity of the licensing firm. Forty percent of private universities take the position that "my institution believes equity and cash are of equal value," relative to just 27 percent of public institutions. These numbers coincide with the AUTM data indicating that a greater proportion of the top 20 institutions that took equity in companies were private as opposed to public. The rule is not absolute, however; while private universities seem generally more open to equity than pubic schools, the top three universities most often accepting equity are public: the University of Arizona, the University of North Carolina at Chapel Hill, and Rutgers University (AUTM, 1997). The survey results in Table 4 indicate that many OTTs are open to accepting equity as compensation. These provide a single time-slice of an ongoing change in policy and practice at many universities in the 1990s: allowing the university to take ownership in private firms. Jensen and Thursby reported that, by 1995 for the 62 institutions they surveyed, 23 percent of the license agreements included equity.

[9] The distribution of earnings in Figures 3.a and 3.b do not show equity or other forms of technology revenue.

Yet, they caution that the magnitude of university ownership of private equity should not be overstated, as only three percent of the total OTT revenues were in the form of equity.

Table 4. ***Equity preferences reported by OTT officials (1999)***

Question	Public universities, percent	Private universities, percent
"My institution will not or is not allowed to consider equity"	10.0	13.3
"My institution prefers cash payments but will consider equity"	63.3	46.7
"My institution believes cash and equity are equally viable forms of payment"	26.7	40.0
"My institution prefers equity"	0.0	0.0
Total	100.0	100.0

Source: Castillo, Parker, and Zilberman, 2000

Even for the top ten technology licensing universities in 1995 the total technology transfer earnings average just 2.5 percent of the university research budgets. Midrange institutions generated revenues averaging just 1.5 percent of their research budgets, and the bottom ten percent generated less than one percent. It is clear that technology transfer revenues do not pay for university research. Furthermore, much of this money does not return directly to the university's research programs but instead goes toward administrative costs.

Licensing revenues, however, are only a small part of the full benefits that accrue to society from university innovations and technology transfer activities. These innovations in the end generate much more income than the OTTs are ever able to realize. If a university receives only three to five percent of the sales, that means 95 to 97 percent must go elsewhere. University innovations lead to spin-off products and, within the legal bounds, copycat or follow-on products. In most cases the returns to these accrue to the firms that shoulder the risk and make the necessary investments to develop processes and products from early stage university ideas and bring them to market. Consumers benefit handsomely from being offered new kinds of products that meet their needs in new and valuable ways. Thus, the revenue numbers presented here tell only a small part of the whole story.

8.b Numbers of university patents

[10] The figures presented here are in nominal terms.

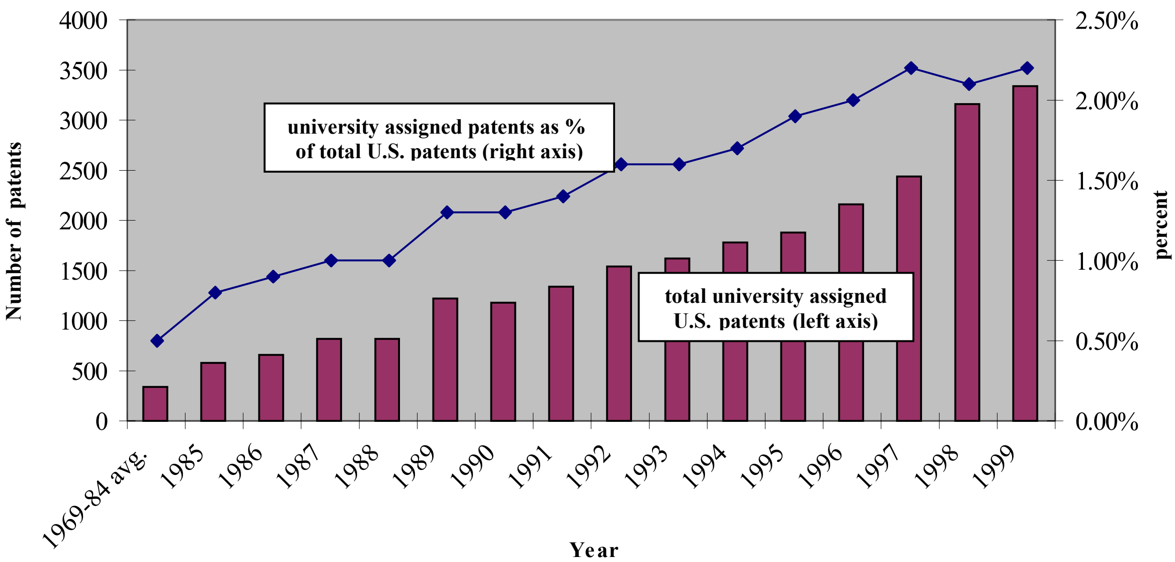
The magnitude of patenting by the university sector, while still small relative to industry, has increased substantially in the last thirty years in absolute numbers of patents and it has increased more quickly than the overall trend of patenting in the U.S. (see Figure 4). The increase in patenting by universities began in the 1970s, even before the passage of the Bayh-Dole Act, but the pace quickened in the 1980s after the Act's changes were broght to bear (Mowery et al., 2001), suggesting that the economic forces that broght that legislation about were perhaps already at work in the years prior to its enactment. Furthermore, the number of patents assigned to universities per research dollar spent at universities has more than tripled (Henderson et al., 1998). This increase in universities' '*propensity to patent*' is due both to an increase in the number of patentable inventions resulting from changes in the orientation of underlying university research agendas and to a general decline in the threshold of university standards for patentability (Henderson et al., 1995). The latter phenomenon likely reflects the large influx of patents from the many smaller institutions with generally weaker research programs and less experience in patenting their inventions.

Figure 5 shows the distribution of the numbers of patents accumulated by the 30 top patenting U.S. universities in 1999 according to the AUTM data. The University of California system dominates the field[11] followed closely by a strong cadre of six other big hitting universities, each with a portfolio of over 80 patents by 1999. After these top seven, the rest of the top 30 universities levels off around an average of 50 patents.

It should be noted that the role of a patent at a university is not as straightforward as it may be at a company. Jensen and Thursby report that in just 28 percent of the cases is a patent issued at the time of a license. In most of the other 72 percent of cases a patent application has been filed, but it is clear that much of the inventive work coming out of the univeristies is transferred out at the pre-patenting stage. The number of granted patents is just the tip of the iceberg when it comes to indicating the value generated by university research.

[11] The UC system represents ten campuses, including several that would stand alone as prominent research universities—UC Berkeley, UC San Francisco, UC Davis, and UCLA. Nonetheless, a single central office of technology transfer exists at the Unviersity of California Office of the President which coordinates the technology transfer activities of the entire system in cooperation with autonomous licensing offices at the largest campuses.

Figure 4. ***Patents assigend to U.S. universities: number and percent of total U.S. patents per year, 1969-1999***



Data source: U.S. Patent and Trademark Office

8.b Licensing revenues and numbers of patents in different fields of technology

Table 5 compares the distribution of the average income and number of patents by academic discipline according to the results of the Castillo, Parker, and Zilberman survey. Biotechnology looms largest in the universities, making up a large part of the fields of both medicine, which dominates in terms of income (earning 55% of the total) and patents (taking 46% of all patents), and agriculture, which generated about nine percent of the income and eight percent of the patents. Engineering and physics accounts for about 24% of the income and 34% of the patents. Computer sciences generated approximately 5% of the income and 4% of the patents. In an in depth analysis of three universities, the University of California, Stanford, and Columbia, Mowery and colleagues (Mowery et al., 2001) found similar patterns. At Columbia, almost 75% of all inventions disclosed to the OTT between 1981 and 1995 were biomedical, the remaining 25% were mostly software and electronics. At the University of California, by 1990, roughly 65% of all inventions disclosed were biomedical. At Stanford, however, only about 20% of all invention disclosures by 1990 were biomedical, while about 30% were in software.

This distribution reflects, to some extent, the divion of research labor between universities and industry as discussed earlier. Many of the technological trajectories played out in engineering and computer hardware are now squarely situated in the mature competitive phase characterized by 'process' developments with many of the industrial applications becoming commodified. Uncertainty is smaller and the markets are well defined. In contrast biotechnology is still in its early phase, i.e. it is very risky and is proceeding without well defined markets. In close relation to the uncertainty and the investment requirements of the stages in the life cycles or the points in the natural trajectories of innovations, profitability is a key factor in determining the allocation of research between private firms and universities in each of the disciplinary or industrial fields. This perhaps explains why much of agricultural research has historically been done in universities though it is mostly related to established mature innovations.

In addition, the data in Table 5 show that for public universities, relative to private universities, a greater proportion of patents and a higher percentage of technology income are in agriculture. Many of the largest public universities are Land Grant institutions with historically strong schools of agricultural science (such as U.C. Davis, Texas A&M, Cornell University, University of Wisconsin-Madison, Ohio State University, Florida State University, Iowa State University, Purdue University, etc.) In addition, while we do not present time series data here, there is some evidence that, even for these public universities, the composition of patents and invention disclosures has shifted from the agricultural field to the more profitable biomedical field (Mowery et al., 2001).

Table 5. ***Average proportion of licensing revenues and patents by academic field (1999)***

Academic field:	Average revenues, as a percent of total			Average number of patents as a percent of total		
	Public	Private	Both	Public	Private	Both
Agriculture	10.3	6.9	9.1	9.5	5.5	8.1
Engineering and Physics	19.8	32.3	24.1	32.2	38.7	34.1
Medicine	55.2	55.2	55.2	44.4	51.0	46.4
Computer Science	5.5	5.2	5.1	3.9	4.2	4.0
Other (including Chemistry)	10.3	0.5	6.6	11.2	0.5	7.4

Source: Castillo, Parker, and Zilberman, 2000

Logic suggests that university royalty rates should be higher in industry sectors with higher overall profit rates or where the relative contribution of research to profitability is higher.

University royalties should be higher particularly in situations where the university has provided a more commercially developed product and thus has contributed more to reaching the market. Table 6 shows royalty rates in a variety of technology fields. The high royalty rates for medical research reflect the relatively high contribution of the university research to the value of marketed products. The average value of the minimum annual royalty payment for diagnostic and therapeutic innovations is much higher than other categories, especially agriculture and medical research. Medical therapeutic license contracts have high up-front

Table 6. ***Key indicators of earnings by field of technology***

Type of product	Average royalty as % of sales	Average value of up-front fixed fee ($)	Average value of minimum annual royalty payment ($)
Agricultural	3.9	20,105	6,928
Engineering	6.3	32,236	16,397
Medical (therapeutics)	6.3	98,437	83,010
Medical (diagnostics)	6.6	36,906	46,227
Medical (devices)	6.6	37,115	38,775
Medical (materials and reagents)	9.4	12,942	4,444
Other (includes chemicals)	7.63	78,583	42,687
All Fields	6.6	45,189	34,066

Source: Castillo, Parker, and Zilberman, 2000

fixed fees. But, there does not appear to be a correlation between the up-front fee and the annual royalty payment. This suggests that there is independence between technology fields. We do not yet have enough data to test for correlation between up-front fees and royalty payments within technology fields.

8.d Numbers of companies started

For a variety of reasons, corporations do not often give university innovations a very enthusiastic reception; to say it another way, Pattern 1 as presented in Table 1 is relatively scarce. Over the last two decades, recognition of this corporate reluctance has prompted OTTs to seek other avenues for the commercialization of promising university inventions. A common strategy that has emerged for OTTs is to facilitate negotiations and relationships between university researchers and venture capitalists in order to start up companies that can finance the further development and commercialization of university ideas. A short list of major companies spawned by university OTTs in the San Francisco Bay area includes Sun Microsystems, Cisco, Genentec, Chiron, and Amgen; all of which followed Pattern 5 in Table

1. Table 7 reveals that across the U.S. the number of start-up companies associated with university innovations has was increasing through the 1990s.

University spawned start-ups play an important role in increasing competitiveness. For example, while the first computers were developed in universities and commercialized by giant companies such as IBM, some of the subsequent breakthroughs that made them more affordable and user-friendly resulted from university innovations made available to consumers via start-ups. Many foundational elements of the Internet were born this way as well; for one, Netscape came out of work at the University of Illinois. Likewise, most biotechnology-based medical treatments are the result of university research. University innovations, once transferred to the private sector, accelerate the rate of product change and force established companies to take action and to adjust to a new reality. In industries such as pharmaceuticals and agricultural chemicals, there are large established players who, if left unchallenged, might choose to slow the rate of innovation and product development in order enjoy a longer time horizon to take advantage of their positions in certain market segments. When start-up companies introduce new products and innovations in those markets they force the large corporations to respond by reducing prices, improving their own product mix, or perhaps taking over the start-up and marketing the new innovative products alongside their own old line of products.

Table 7. ***Spinning out: the number of start-ups based on university inventions 1980 to 1999***

Year(s)	Number of institutions reporting	Start-ups formed
1980-1993	N=154	1,169
1994	N=156	241
1995	N=172	223
1996	N=168	248
1997	N=171	333
1998	N=176	364
1999	N=188	344
Total		2,922

Source: AUTM Licensing Survey, FY 1999

8.e Skewed distribution of outcomes from university research

The lopsidedness of OTT earnings, as seen in Figures 3.a and 3.b, reflects a very important general fact about the odds on returns to investment in upstream research: it is quite rare to make a hit, but when it is made it can be very big. A handful of university patents, including the Cohen-Boyer patent for genetic recombination (Stanford and University of California-San Francisco), the Hepatitis B vaccine patent (University of California-San Francisco), the Taxol patent (Florida State University) and the Gatorade sports drink patent (University of Florida), have each generated tens of millions of dollars over their lifetimes. Most university patents, however, generate incomes ranging from zero to just a few tens of thousands of dollars.

Scherer and Harhoff (2000) have compiled extensive data on the financial returns to broad sets of patents, both industry and university, and find that this kind of skewness of returns is typical for outcomes from research. They find that the value distribution of patents can be so skewed that the average rate of return on investments to a portfolio of patents can be completely determined by the size of its few biggest outliers, which raises questions about the viability of typical portfolio management strategies. A patent portfolio where more than half of the 'investments' fail to earn anything at all and where only one in twenty yields appreciable returns appears indeed to be a normal state of affairs. It is reasonable then to ask what the determinants of success are for university technology patenting and transfer, in order to help pick the winning technologies and design mutually beneficial policies for technology transfer.

9. Successful technology transfer is a function of OTT age, research quality, and inventor involvement

Several general factors have been observed to play roles in the overall success of university efforts at technology transfer, and attention to these factors can be important for company managers looking to universities as a source of new technologies. First, the age and professional experience of a university's OTT matters. It takes time to develop an expertise in intellectual property management, to build up a portfolio of patents, and to sucessfully sell and manage the many contingencies that can arise with technology licenses. There is typically a four to nine year lag between making an academic research discovery until the first introduction of a new commercial product or process based on that discovery (Mansfield, 1991). Even after the market debut of a new technology, slow rates of technology diffusion and adoption[12] can mean that royalties grow only gradually. As a result younger OTTs tend to lag significantly in their earnings relative to older OTTs. Indeed, the top ten ranked OTTs

[12] The literature on diffusion suggests that the relationship between adoption (and thus earnings) and the age of an innovation is S-shaped, with a slow early build-up period, a subsequent rapid take-off, and then a slow-down approaching saturation (Griliches, 1957).

in terms of revenue are predominantly the older ones; however, over the last ten years their share of the total number of university licenses and total university royalties has decreased, reflecting the greater licensing and revenues of the younger OTTs as they mature (Table 8.)

Table 8. ***Relative performance of the top ten university OTTs in 1992, 1995, and 1997***

	Top 10 in 1992, as percent of 1992 totals	Top 10 in 1995, as percent of 1995 totals	Top 10 in 1997, as percent of 1997 totals
Licenses	52.5	43.8	43.1
Royalties	71.9	67.5	64.1
Research expenditures	38.2	33.6	33.9

Source: AUTM (various years), reported in Castillo, Parker, and Zilberman, 2000

The fact that the dominance of the top ten OTTs has decreased more in total numbers of licenses than in royalties results from the time lag for newer OTTs between licensing and royalty collection as more and more new licenses have come on line against a backdrop of many older OTTs that were highly ranked because of older individual big hits (such as Taxol at Florida State and the Cohen-Boyer patent of UC San Francisco and Stanford). Since it is impossible to accurately predict where the next big research breakthrough will occur, there is an element of sheer chance in capturing those kinds of big research hits. For a university, the longer it has an OTT business, the greater is the statistical probability of licensing a breakthrough invention. For a company or investor shopping seeking potentially lucrative undeveloped technologies, approaching older OTTs means working with more experienced professionals who have dealt with success in the past and know to handle it when it happens again.

Another identifiable force behind the success of a university's technology transfer is, not surprisingly, the university's academic standing together with the amount of research dollars spent on research in the fields that tend to matter commercially, such as biology, medicine, engineering, and computer science (as indicated in Tables 5 and 6.) Highly ranked research institutions such as the University of California, Stanford, Columbia, and MIT are the leading technology income earners among U.S. universities (Figure 3b). While many of the applied programs at smaller universities can and do produce technologies that are highly valuable, all else being equal, one should look for cutting edge technologies at leading institutions. As a rule of thumb, approach the OTTs at schools where you would want your children to go to college and which have respectable programs in the 'majors' in which you are particularly interested.

Finally, ongoing inventor involvement is essential to successful technology transfer. Only the university inventor can communicate all the ins and outs of an invention to a licensee who will develop, produce, and market a product based on it. A successful transfer requires knowledge and know-how at both the sending and receiving ends. Jensen and Thursby find in their survey that most university inventions at the time they are licensed are little more than 'proof of concept' disclosures (48%) or laboratory scale prototypes (29%), and they emphasize that most licensed inventions (71%) require inventor cooperation for successful commercial development.

10. Summary and Conclusions

10.a General Summary

Today, universities pursue multiple objectives, both public and private, and in so doing rely on a variety of funding sources, also both public and private. This diversification allows university scientific research to emphasize work that is largely described as 'basic' but which occasionally and rather unpredictably results in practical technologies that can be very valuable when applied commercially.

Technologies have a tendency to develop along relatively clear paths or 'technological trajectories', resulting from research that repeatedly focuses on a particular class of problems or uses a particular breakthrough discovery as its starting point. In the early or 'basic' phase, research in a new paradigm tends to be more uncertain, and its return horizon is often quite long. If public support is not available it is not likely to be pursued. However, if and when more certain 'applied' innovations, promising sufficient economic returns, emerge within such a problem solving paradigm, venture or corporate investors will begin to be able to afford to support further R&D in that technology. The work leading to an eventual product release will be observed to have passed through four stages: research, development, production, and marketing.

The very different financial constraints of universities and companies translate into rather different sets of objectives and incentives for the individual researchers they employ which encourage them to specialize at different stages within these patterns of technological growth, in response to the varying probabilities of success. The private objectives of all scientists can be summed up as a pursuit of some combination the three 'F's—*fame*, *fortune*, and *freedom*. In the university these are pursued by seeking original and creative solutions to a diverse array of significant problems, resulting in a broad portfolio of university innovations, of which a few turn out to have enormous value but most offer little or no economic value. In industry, researchers pursue the ‘F’s by focusing research and developing technologies to contribute to the firm’s ability to create value. Industry scientists are largely limited to working on improvements in proprietary processes or products that are held by the company which are likely to yield sufficient returns within a reasonable time horizon.

The link between university inventors and industry is provided by universtiy Offices of Technology Transfer (OTT) which manage the intellectual property of universities with the goal of commercializing inventions and earning revenues. Commercialization is achieved either by licenising a patented invention to an existing company, or by helping the university inventor to obtain venture capital to start up a company that will commercialize the technology. The essence of the technology transfer process is to supply companies with new ways to meet customers’ needs.

10.b Conclusions for policy makers and university officials

Government policies and support have enabled universities to discover and develop breakthrough technologies that have changed the economy. A string of massive public support for research in defense, aerospace, medicine, agriculture, and the environment, along with federal funds for more targeted problems and financing of higher education, has historically supplied the foundation on which universities have flourished. U.S. patent law, together with the Bayh-Dole Act of 1980, provide a framework that enable universities to retain the title to their new technologies and innovations. Offices of technology transfer have begun to capitalize on the new legal possibilities for transferring knowledge that arises in the public sector and now play a crucial role in developing the networks for exchange between university researchers and potential users of their research results in the private sector. The result is the engine of educational-industrial complex: univerisity research plays essential roles setting the pace of innovation in the economy, creating new technological paradigms, and breaking old technological bottlenecks. A powerful combination is achieved at the university in the co-production of human capital and intellectual capital, with education and training complementing research and inventing. Investment in university research does not just result in research for its own sake, but serves to constantly maintain and upgrade the knowledge infrastructure of the economy.

University research also can be viewed as an important source of competativeness in the economy and could be promoted as part of anti-trust policy. If universities are encouraged to continue the innovation and commercialization of new technologies, they can be expected to generate a constant flow of new ideas and new entrants into the economy.

Finally, it is reasonable to assume that the marketing of university research would benefit from economics of scale, meaning that, at least to an extent, the larger the represented research base, and thus the larger the portfolio of new technologies made available to license, the lower the marketing costs and the higher the probability of successfully selling licenses. These conditions could be achieved, for instance, if several universities used a single OTT to market their innovations, a move that would increase the variety and depth of technologies available and thus increase the attractiveness of the combined-OTT to potential business customers. However, in actuality, universities appear to be seeking to market their research results independently. Each university's first goal in marketing its research appears to be demonstration of its research vitality to potential public and private research funding sources rather than simple maximization of earnings from licensing. Even so, it would be much more efficient for technology transfer if interested companies could go to one place that hosts a full variety of research results and new product innovation opportunities. A viable alternative may be the establishment of a middle-man organization which respresents and markets the products of multiple university OTTs.

10.c Conclusions for company managers

Marketing and strategic management scholars argue that there are two sources of ideas for the innovation of new products. The first source, advocated by the customer orientated approach, is "listening to your customer's voice." A company first identifies the needs of customers (both potential and existing customers and both their stated and hidden needs) and develops a new product; identfying the gap between customers' demand and the current supply offered by you and your competitors opens up a strategic opportunity.

Supply driven innovations, development of new products based on new technological capabilities, can be more risky. Inventions that are the outcome of university research are by their very definition supply driven innovations (although it is possible to argue that most basic research arises as a response to society's more generally articulated needs). They have potential to succeed, but, to the extent that they were developed with technological opportunities and not consumers' needs in mind, their rate of acceptance by the market and their final value is uncertain. In fact, according to classical marketing management perspectives, the pursuit of product innovation from the supply side is considered by some to be downright myopic. In his paper "Marketing Myopia" Theodor Levit wrote, "Another big danger to a firm's continued growth arise when top management is wholly transfixed by the profit possibilities of technical research and development." (Levit, 1960). Kotler (1997) expounds on the theme: "Under the [product] concept, managers assume that buyers admire well-made products and can apprise product quality and peformance. However these managers are sometimes caught up in a love affair with their product and do not realize that that the market is less turned on. The product concept leads to kind of marketing Myopia..." One way to avoid this downside of technology driven innovation is to conduct market research, asking customers what they think, at the research or development stage, before moving into production.

These two sources of product ideas, i.e. customers' unfulfilled needs and university research, can be used simultaneously and made to complement each other. Customer's needs can be used for short term planning since it requires usually product improvement and upgrading while the commercialization of new research products is more long run activity. Implementation of applied research is always more easy and fast than the implementation of basic research which needs higher capabilities and resources. However, the rare company that succeeds in adopting and implementing basic research gains huge competitive potential.

One important conclusion is that private companies should build mechanisms to help them identify research done in the universities and screen it according to its marketing potential. Once a systematic identification of research is implemented a company has a constantly updated base of new ideas to work with. The next step is to screen these ideas regularly and select according to both market needs and probability for successful research completion.

In closing, a short list of suggestions for R&D managers to consider:

1. Look beyond just the technologies in the current product market. Do not regard university research as remote or irrelevant. You will miss great opportunities or may get undercut by new technologies you did not see coming. Instead, try to identify successful research teams at universities. View faculty as resources on which to draw. Establish mechanisms for detecting new technologies and new talent in the universities. Learn before others what kind of work is going on in universities.
2. Develop an R&D strategy that takes into account technologies available from universities. Seek cost effective options for licensing and technology transfer. Shop what is 'on the market' from universities. In some cases you will be able to avoid reinventing the wheel. It may cost less to license rather than to make something comparable from scratch. Diversify your R&D strategy:
    i. work in house, but

ii. recognize that the best value may be to augment from outside. For example consider how Microsoft or Cisco regularly buy up small firms with proven technologies from outside and integrate them into the company.

3. It is essential to capture technologies from at the appropriate stage in their evolution: not too early, not too late. It is the age-old balance of exposure to potential losses versus potential benefits.
4. Establish a venture fund to sponsor specific university projects or teams. You may be able to negotiate 'first right of refusal' from a university. If you are not ready to shoulder the full investment by bringing a technology in house. Your venture fund could partner with other investors to create an independent firm to develop the technology. This limits your exposure if the technology does not work out.
5. Keep an eye on the startups coming out of universities. They have already passed through one stage of screening for commercial viability and are a good indication of what is availbable. It is possible to approach such startups to license the technology they bring from the university or to contract them to develop the technology to meet your company's needs. This again may be more cost effective or a better way to manage the risk than to internalize the technology directly.
6. Move technologies out from your company that do not belong in your portfolio. Do your own technology transfer: license to other firms; create your own startups with the help of venture capital; donate blocks of patents to universities, non-profits, or the government.

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