The Emergence and Standardization of University Technology Transfer Offices: A Case Study of Institutional Change

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Patent management is a complicated business and is expensive. It requires a high degree of legal competence, administrative astuteness, and promotional zeal--a combination of talent not always readily available in an educational institution. The patent search is a specialized technical job. The preparation and processing of patent applications is exacting work for legal counsel. The administration of patent rights demands careful attention to intricate details and constant watch for infringement. The exploitation and disposal of patents, through sale and licensing agreements, requires salesmanship of a high order. It is natural, therefore, that most educational institutions make every effort to avoid becoming directly involved in the intricate legal and commercial aspects of patent management.
--- Archie Palmer (1947)

Almost all research universities in the United States have technology licensing operations.
--- Lita Nelsen (1998)

I. Introduction

Institutions and institutional change are again fashionable topics in economics, and across the social sciences more generally. Despite, or perhaps because of, its broad intellectual appeal, the concept of an "institution" means different things to different scholars. Perhaps because of this, an empirical research program on institutions and institutional change that has breadth and cumulativeness has yet to emerge. In a recent paper (Nelson and Sampat 1999), we developed a notion of institutions that is both broad enough to encompass and bring in many of the concepts of institutions found in the recent literatures, and concrete enough to form the basis for an empirical research program. Specifically, we associated institutions with standardized "social technologies", where social technologies are the components of broader productive routines that direct division of labor and modes of coordination.

This paper develops this concept of institutions as standard social technologies further, by examining a particular instance. To explore the viability of the conception, we focus on social technologies relating to the patenting and licensing of university inventions.

We begin Section II by relating our conceptualization of institutions to others in the literature. In Section III, we overview the social technologies discussed in the paper. Section IV is the heart of the paper, where we present the case study. Based on this case study, in Section V we reflect on central questions in the literature on institutional emergence, institutionalization, and institutional change.

II. Institutions and Standardized Social Technologies

We begin by briefly reviewing the argument and proposal we made in Nelson and Sampat (1999). Writings about institutions in economics--both recent and older--implicitly or explicitly contain a wide variety of definitions of what is meant by the term "institution". We argue that Veblen's "general patterns of action and thought," Schotter's "how the game is played," North's "rules of the game," Williamson's "governance structures," Commons' "working rules," and other conceptions of institutions put forth by distinguished economists and social scientists all have a family resemblance. Specifically, virtually all economists writing about institutions have aimed to call attention to standardized modes of transacting, and interaction more generally, employed by human and organizational actors to get things done, that are not adequately explained in terms of the utility or profit maximizing calculations across roomy choice sets that are the bread and butter of explanations of human behavior in standard neoclassical theory, and which seem to require in addition or in substitute some kind of statement about expectations, norms, or constraints that focus the attention on particular standard ways of doing things. However, the different institutions concepts vary in the weights given to, on the one hand, the characterization of the standardized behavior patterns per se versus the reasons for the existence of such patterns, and, on the other hand, the weights given to different elements or variables in the explanation.

Our view of what is common across economists' concepts of institutions, and what is divergent, led us to propose that the best focus for a theoretical and empirical research that had the promise of being cumulative would be on the generally employed behavior patterns per se. We believe the such a focus has two major advantages. First, it orients the analysis, right from the start, towards the phenomena that virtually all analysts are interested in explaining. Further, the object of such a focus is describable in reasonably straight forward ways, and can be studied empirically through a variety of different routes. Second, the analysis is open regarding the

factors and forces that lie behind the standardized behavior in question. In some cases it might be a body of formal law. Particular organizational forms might be involved in an essential way. Strong norms might or might not be associated with the body of practice. Our argument is that what lies behind, what causes the emergence of, and what holds in place, standardized patterns of human and organizational transacting and interacting should be an open research question. There is no reason to believe that all such standardized transacting patterns are held in place by the same things.

However, we proposed that virtually all institutionalized behaviors shared two supporting elements. First, they were "low transaction cost" ways of doing things, because they were customary and expected, and also because they tend to be meshed with complementary patterns of behavior. Second, because they were customary, and widely employed, they tended to be sharpened and honed by cumulative social learning. For both of these reasons, institutionalized ways of doing things tended to have certain economic efficiency attributes.

We used the term "social technologies" for such institutionalized ways to get things done, both to flag their instrumental role, and to connote that they had certain things in common with the "physical" technologies that most economists have in mind when they talk about technologies. We proposed that a wide variety of economic activities involve both a physical technology, which is recipe like, and a social technology, which defines a division of labor or a set of differentiated roles, and a coordinating mechanism. Both a physical technology and a social technology can be characterized as a set of routines, to use the language of Nelson and Winter (1982).

Our central argument is that such social technologies are much of what economists writing about institutions are interested in. Our proposal is to define institutions as the customary, expected, social technology used for a particular set of purposes in a particular context, should such a customary and expected social technology exist. Thus this institutions concept correspond to "widespread habits of action" and "the way the game is played". In our

conception, most standard technologies have a range of flexibility so as to be suitable in a number of particular contexts and for particular purposes. Thus they do not uniquely define choice, but rather channel it. Our institutions concept then is consonant with the notion that they are “the rules of the game” when these are regarded as determining the structure of game, that is what people do when they play the game.

We understand that some social scientists might want to reserve the term institutions for something broader than that, or to factors that mold social technologies, and we do not want to quarrel about language. But we believe that generally employed social technologies in fact are the subject matter of most writings about institutions.

III. Social Technologies Relating to University Patenting: An Overview

Our focus in this paper is on a particular set of social technologies, those relating to patenting (and licensing) university inventions. The research university itself is a complex bundle of routines, and those relating to how research is done and research results are disseminated have traditionally been conducted according to the modes of interaction that have been characterized as the "institutions of open science" (see e.g. David 1998, 16). Under this mode of behavior, scientists typically are committed to disclosure and wide dissemination of their research results (Merton 1973), and other scientists are presumed free to use these results in their own research. This behavior is induced and supported (or according to Dasgupta and David 1994, made incentive compatible) by a reward system emphasizing priority.

Given this, throughout the century academic scientists generally were not been centrally involved in patenting their inventions or licensing them. Thus Merton (1973) observes that "property rights in science are whittled down to a bare minimum . . . [t]he scientist's claim to his intellectual property is limited to that of recognition and esteem" (267). The norm against patenting is also seen in the statement of Nobel prize winning physicist I.I. Rabi of Columbia in

his 1946 testimony to the Senate that "a patent minded colleague in our department would in time find that he has few scientific friends. We like to discuss matters freely and it gives us the jitters to feel that someone is going to rush off and patent some idea which comes up" (quoted in McCusick 1948, 203).

This is not to say that, on occasion, some university professors did not patent inventions. Indeed, there are a number of prominent examples of this. And of course, it is also not to say that universities did not do research of commercial importance. As Rosenberg and Nelson (1994) have documented, there is a long tradition of universities transferring knowledge and technology to firms, though this has typically (and probably still does) taken place mainly through channels like publication, consulting, and presentations at professional conferences.

This non-involvement by universities changed gradually over time, and reflecting on these changes is useful in thinking about institutional change. However, there appears to have been something of a more dramatic change recently.

By the late 1980s, the following set of routines had become virtually ubiquitous at research universities. Faculty members who come up with inventions or discoveries of potential commercial importance are required to file an “invention report” with the university, which, among other things, describes the invention and the anticipated uses. The report is studied by the staff of a university "technology transfer office" assigned responsibility for the activities of the university in patenting and licensing. If that office judges it worthwhile, it arranges to get a patent application filed. The university holds title to that patent if it is issued. That office also is responsible for negotiating license terms with any firms that want to use the invention. Any license fees are divided on a formal basis between the inventor, his or her laboratory and/or department, and the central coffers of the university.

This mode of behavior and cross-organizational interaction has become a standardized social technology, or an institution. To be concrete, we will refer to this mode as the "technology transfer office" model; however, it is important to keep in mind that by this term we refer to the

mode of behavior and interaction supported by these governance structures and policies, rather than to the organizational arrangements alone.[1]

To an audience composed primarily of academics, it should not come as a shock to say that there is little evidence that open science does not still prevail at universities. The new social technology has been nested within the bundle of routines that characterize the research university. However, as we point out below, and as is discussed at length by Argyres and Liebeskind (1998), this was not done seamlessly, and is not without problems.

In the next section, we consider in detail universities' social technologies for dealing with patents and licenses, and the emergence and institutionalization of the "technology transfer office" model.

IV. The Emergence, Evolution, and Standardization of Social Technologies: A Summary History of University Patent Policies and Procedures

Early Precedents

As we suggested above, in the early decades of the century, it was rare that university research results would be considered for patenting. However, if a patentable invention arose in the course of a university faculty members' research, that faculty member typically filed a patent application and possibly attempted to shop the invention by himself. In cases, firms that had heard of the invention "through the grapevine" might themselves contact the licensee.

University administration would not typically become involved in this process, reflecting their lack of expertise in this area and difficulties--in particular among the more traditional research universities--of reconciling dealing in patents, which granted monopolies on knowledge and technique, with the norms of open science. In addition, patents were uncommon occurrences,

[1] In Nelson and Sampat (1999) we note that in some cases it is convenient to refer to a particular standardized social technology by using the name of the particular background factor or structure associated with it. Thus to call Chandler's M-form an institution is a convenient way of referring to the social technology of corporate management associated with it. Similarly, some physical

making it unnecessary and inefficient to set up policies or procedures that governed them. An exception to this was in the field of medicine, where several universities, including Columbia, Harvard, and Johns Hopkins, actually began in the 1920s and 1930s to forbid faculty members from patenting.

However, "exceptional circumstances" had led some universities to become more involved in patents. As we emphasize below, there was considerable uncertainty about the "right" way to proceed, and the actions taken by these universities in these contexts served as prototypes to which other universities latent turned and from whose experiences other universities benefited.

The University of Toronto's acceptance and licensure of the Banting-Best insulin patent was among the first such precedents.[2] In 1921, Toronto scientists Banting and Best developed a process for extracting pancreatic secretions to treat diabetics, i.e. for the production of insulin. The scientists considered simply publishing the method, in hopes that interested firms would attempt to develop a product based on the publication. However, they feared that if they did not patent the discovery, other "pirate" firms may do so instead, potentially imposing hurdles on their own continued research programs and monopolizing the industry. Second, they feared that without a patent, an unscrupulous or incompetent firm might produce an unreliable version of insulin, thus tarnishing the scientists' and university's reputation.[3]

It is important to note that this decision to patent did not come without considerable debate. Banting, one of the co-inventors, was initially very reluctant to patent the invention, feeling that this would be a transgression of medical norms. However, eventually did so, because he was convinced by his co-inventors and outside sources that patenting would be in the public interest.

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technologies are named in terms of the equipment used to implement them, e.g. the "open hearth" method for making steel.

[2] This discussion draws on the histories presented in Bliss (1983) and Swann (1988)

[3] There is a long tradition of inventions being exploited by unqualified or unscrupulous firms and individuals. See e.g. James Harvey Young's *The Medical Messiahs: A Social History of Health*

The inventors, unable to administer licenses themselves, assigned the patent over to the University of Toronto. The Board of Governors of the University created the Insulin Committee (a small administrative committee) to handle the patent. The Committee's was to overseeing quality control of the invention, which included managing the licensure of the invention. Importantly, though the University would accept assignment of patents if offered, it had no general policy compelling other inventors to report patents or patentable inventions.

Toronto's actions were important serving as a reference point for other universities. In 1924, Dr. Harry Steenbock of the University of Wisconsin demonstrated a method of increasing the vitamin D content of food and drugs via the process of irradiation. Steenbock, despite the criticism of many in the medical community and his colleagues at the University, decided to patent his findings. It appears that primary rationale for patenting was to protect the public from unscrupulous or incompetent firms and from potential monopolization of the industry by a private patentee (Apple 1996). Steenbock cited Toronto as a precedent, noting that the researchers there patented to insure that "the public is protected against the manufacture of poor preparations and is also protected against the extortionate charges" and to "avoid the possibilities of misusing [of] their discovery which not only would have retarded the further development and use of this product, but would also have resulted in causing untold suffering among diabetic patients" (as cited in Apple 36).[4]

Once the decision to acquire the patent had been made, the question remained of how to administer it. Steenbock offered to assign the patent to Wisconsin, just as the insulin researchers had done in Toronto. However, the University was not convinced that creation of an administrative organ to handle patents was worth the necessary investment (Apple 1996). Thus a different solution was developed. Steenbock convinced several alumni to create administrators to

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Quackery in Twentieth Century America and *The Toadstool Millionaires: A Social History of Patent Medicines in America Before Federal Regulation.*

create the Wisconsin Alumni Research Foundation (WARF), a university affiliated but legally separate foundation that would accept assignment of patents from University faculty, would license these patents, and would return part of the proceeds to the inventor and the University. According to Apple (1996) the idea was that "[w]ith this structure, business matters would not concern or distract the university from its educational mandate; yet academe could reap the rewards from a well-managed patent whose royalties would pay for other scientific work" (42).

The Steenbock patents were licensed exclusively to Quaker Oats for use of the process in cereal products, and to five pharmaceutical licensees for the development of vitamin D supplements.[5] Other well known food and pharmaceutical licensees were denied licenses to the process, causing a number of observers to question WARF's devotion to the public good. There were some speculation that irradiated products would be considerably less expensive if manufacturers did not have to pay royalties to WARF. Undoubtedly, the Foundation's high profits were the trigger for some of the concern: by 1936, the patents had earned $700,000 for the University (Spencer 1939, 27). As we discuss below, these concerns about narrow licensing and profiteering would affect the course taken by other universities over the next decades.

More so than Toronto, WARF served a powerful example to which other universities turned beginning in the 1930s. In that decade, universities began to more actively consider patent matters as a result of several forces. First, the Depression has taken its toll on university finances, causing them to be less conservative in looking for sources of income. Second, the post-World War I growth in industrially funded research, led some universities towards consideration of patent policies which would clarify ownership provisions. Finally, WARF's profitability likely whetted the appetites of some university administrators and trustees.

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[4] Apple (1989) also notes that another more or less unstated reason that Steenbock wanted to patent the invention was to prevent margarine producers from acquiring the process, thus protecting the region's dairy interests.

[5] In contemporary legal jargon, the invention was co-exclusively licensed for the pharmaceutical field of use.

The land grant universities (which also often had associated agricultural and engineering experiment stations) were the most active along these fronts. As is well known, the land grant model emphasized that research be attentive to the needs of local industry, often relying on industry contacts for funding in return for teaching or research in particular fields. A number of land grants set up university affiliated but legally separate research foundations--mimicking WARF--beginning in the late 1920s and early 1930s.[6] In most cases, these research foundations were focussed on governing and nurturing contacts contracts with universities generally: McCusick (1948) notes that "patent administration was only incidental to [their] primary purpose" (2). Also, with the exception of Illinois, this group of schools did not assert rights to university research; however, faculty with patentable inventions could ask the research foundation to hold and administer the inventions.

The Massachusetts Institute of Technology (MIT) is another land grant that drew on the WARF experience. Like the other universities discussed above, MIT did not have well defined patent policy before the 1930s, typically leaving inventions to individual faculty or to industrial sponsors. However, beginning in the 1930s, there was a broad scale rethinking of all aspects of the Institute's relations with industry: patent policy was among the issues on the table.

In McCusick's (1948) study of the development of MIT's patent policy, he notes that "through the years the men responsible for the patent policy of the Institute constantly exchanged experiences with other universities. Thus the development of MIT patent policy was an outgrowth of the general university experience" (206). In particular, the WARF model and WARF's experiences appear to have had considerable impact on the formulation of MIT's policies and procedures. While the Institute welcomed the possibility of generating revenues from its patents, it was wary of the scrutiny and criticism that WARF had attracted (Fishman 1996). To insulate itself, MIT opted to work with a "third party" technology transfer agent, the Research Corporation.

[6] This group included Purdue, Minnesota, and Cornell, among others.

Research Corporation was founded in 1912 by Berkeley chemist Frederick Cottrell to commercialize his patents on the electrostatic precipitator, a pollution control device.[7] Cottrell wished to use the royalties from this invention to fund scientific work, primarily in the universities. However, he also envisioned that some day, Research Corporation might also administer patents for other academics who, like him, were interested in donating all or part of the royalties for research. Over the first two decades of its existence, its activities focussed on its precipitation activities. However, by the late 1920s, a number of academic inventors did turn to Research Corporation for help in administering their patents. This was for a number of reasons. First, they were impressed by its success in managing Cottrell's precipitation patents and related patents in the precipitation field. Indeed, it was well known that Research Corporation had developed considerable expertise in patent management via its experience with the precipitation patents. In addition, recipients of Research Corporation's grants somewhat naturally turned to Research Corporation when potentially patentable directions emanated from their research programs (though they were not contractually obligated to do so).

MIT's patent policy was modified in 1932 to assert its rights in any patentable results from Institute funded research. In 1937, MIT signed the first invention administration agreement with Research Corporation. Under the terms of the agreement, MIT would disclose to Research Corporation inventions that it deemed potentially patentable. Research Corporation had exclusive right of first refusal to these inventions, and agreed "to use its best efforts to secure patents on inventions so assigned to it and to bring these inventions into use and derive a reasonable income therefrom" and further to "use its best efforts to protect these said inventions from misuse and to take such steps against infringers as [it] may deem for the best interest of the parties hereto, but with the general policy of avoiding litigation wherever practicable."

[7] This section, and the discussion of Research Corporation in subsequent portions of this paper, draws on Mowery and Sampat (1999).

All services were provided at the expense of Research Corporation. Any license income net of expenses were to be divided according to a formula by which MIT split net royalties with Research Corporation on a 60/40 basis. Research Corporation was to use its portion of the earnings to support it grants activities. It was the general policy of Research Corporation to only give non-exclusive licenses, perhaps a response to the criticism that exclusive licensing by WARF has provoked.

Research Corporation's agreement with MIT buttressed the former's position as a major player in this field, and set an example to which other universities turned. Princeton and Columbia were among the other universities that signed invention administration agreements with Research Corporation in the late 1930s.[8]

Despite these instances, before World War II most universities had no patent policies nor had any generally followed procedures: instead, patents and related matters were left to individual inventors or were governed by terms of industrial research agreements. Some had policies that "they will patent nothing in medicine and leave other patentable discoveries to the disposition of the discoverer or inventor" (Spencer 1939, 23). To the extent that there was a standard social technology, it was "don't get involved in patents".

Even before the Second World War, however, activity was beginning to bubble. Spencer, writing in 1939, notes that:

> "During the last decade, the number of universities which have adopted well defined policies in regard to inventions made by their employees, or with the aid of university equipment, has steadily increased. Additionally, there are today many other universities actively considering the adoption of a 'Patent Policy' and it is likely that another ten years will see such a policy in every school in the country that offers scientific or engineering courses" (Spencer 1939, 1).

[8] These universities, however, did not assert rights to faculty inventions. Disclosure was voluntary, and most disclosed inventions were immediately handed off to Research Corporation.

We have observed that in forming policies and setting up procedures, universities typically looked to one another's practices and experiences. [9] As we will point out below, this trend would continue through the postwar era and to this day.

The Impact of World War II

The impact of World War II on university research is well known. Via the successes of the Manhattan Project and projects funded by the Office of Scientific Research and Development (OSRD) scientists in academic laboratories were seen as having won the war. The result was a consensus among policymakers to dramatically increase the amount of federal funding for extramural research, most of which would be conducted in the nation's universities. The increased volume of military and biomedical research conducted in the universities during and after the war increased the pool of potentially patentable inventions. More importantly, the growth of federally funded research focused the attention of U.S. universities policies governing the patenting of the results of federally sponsored research, just as the growth of industrial funding had done, to a lesser extent, in the 1930s. Palmer's survey conducted in the late 1950s (Palmer 1962) found that 85 colleges and universities had adopted or revised their patent policies during the 1940-55 period.[10]

Nonetheless, at the end of World War II there remained considerable variety in the policies and procedures across universities. Palmer (1947) noted:

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[9] Indeed, the Spencer survey discussed above was commissioned for Northwestern University as "an attempt to draw coherently upon the past experience of numerous educational institutions and from the knowledge thus gained to formulate a sound and definite patent policy". The Palmer surveys that we draw on below were initially conducted as a report for the Association of American Colleges and later were funded by the National Research Council's Committee on Patent Policy, as it attempted to determine how to best dispose of rights in inventions that it sponsored. The surveys served the important purpose of selling the value of patenting to universities, and providing blueprints of how universities might proceed in setting up patent policies and administrative procedures. Indeed, the Research Corporation later noted that the publication of the 1934 Palmer study "was of great importance to [it] in initiating its work in patent management for educational institutions" (Research Corporation Internal Annual Report, 1946).

[10] Of these 85 policies, 3 were adopted prior to 1930; 6 between 1931 and1935; 12 between 1936 and 1940; 19 between 1941 and 1945; 25 between 1946 and 1950; and 20 between 1951 and 1955.

> At the present time there is a wide diversity of practice among educational institutions--and even at the same institution--in dealing with patentable discoveries and inventions growing out of scientific research. There is no common pattern of policy statement, administrative procedure, recognition of the inventor determination of equities, assignment requirement, patent management plan, distribution of proceeds, and protection of the public interest. Nor is there any convenient grouping according to the size of an institution, complexity of university organization, or kinds of research undertaken" (648).

Again, there was no standard social technology across research universities. Over the next two decades, there was considerable convergence within types of schools on procedures followed, if not on policies. Partly in anticipation of the postwar growth in the scale or research, and partly in response to the already growing demand in the immediate prewar years, in 1946 the Research Corporation established a Patent Management Division. The idea was to extend the "third party technology transfer" agreement that it had with MIT, Columbia, and Princeton to other universities.

Under the terms of such agreements with Research Corporation, university faculty submitted invention disclosures to the Patent Management Division, which bore all costs of invention evaluation, patent prosecution, and licensing. Firms wishing to license inventions would negotiated directly with Research Corporation. The invention administration agreements were fairly standard across institutions, save slight differences in the "sharing rules" between Research Corporation, the university, and the inventor.

This third party model offered several benefits. As noted above, many institutions had already followed WARF and set up university affiliated "research foundations" to handle patents. This was partially because in these structures patent management activities could be combined with other industrial research related activities, which were common at former land grant schools with agricultural or engineering research stations. However, as the WARF example illustrated well, even legally separate but affiliated research foundations that were seen as seeking profits over the public good could cause the University to come under attack. Contracting out thus

buffered the university from this scrutiny while accommodating inventors who needed assistance in patenting and allowing the university to share in any profits that might result.

In addition, there was a "division of labor" argument for using a third party agent like Research Corporation. Beginning with MIT, universities were not keen to get involved in the intricacies of patent management, reflecting the costs and complexity of this activity. Significant fixed costs are associated with establishing an office, creating an administrative structure, developing a record keeping system, staffing up, developing academic and industrial contacts, and the like. These fixed costs, combined with the fact that most institutions could only expect a handful of patents annually, meant that it was generally inefficient to operate a patent management organization on a small scale (Palmer 1948). Thus, there were both political and practical reasons that universities chose not to get involved in these activities.

Table 1 shows the dramatic growth in Research Corporation's invention administration agreements over the next decades:

TABLE I HERE

To look at this from a different vantage point, fully 14 of the 20 largest research universities (as ranked by R&D expenditures in 1963) [11] had invention administration agreements with Research Corporation.[12]

As more universities contracted Research Corporation, it became even more attractive to universities that were in deliberations about how to handle patents. This "network effect" resulted in part from the emulative instinct. Indeed, emulation of peer universities was desirable was not only because universities do not like to be too different from the standard, but also because

[11] These 20 universities included MIT, Columbia, Michigan, Berkeley, Harvard, Chicago, Stanford, UCLA, Illinois, New York University, Minnesota, Cornell, Pennsylvania, Johns Hopkins, Wisconsin, Yale, Washington (Seattle), and Pittsburgh.

[12] Those that did not were Wisconsin (which relied on WARF), Illinois, Minnesota, and Ohio State (which had their own research foundations), and Berkeley and UCLA (which relied on the University of California Board of Patents).

following widely practiced routine allowed them to rely on the collective knowledge and experiences of others. This is a point we return to below.

Though the procedures for prosecuting and administering patents was fairly standard by this time, there remained considerable variance in patent policies (e.g. whether a policy existed, whether disclosure was voluntary or mandatory, whether there were restrictions on patenting medicine) and, consequently, on the universities involvement in the early stages of the process.

Most universities were too small to be concerned with such matters: of the 945 universities that Palmer surveyed in the late 1950s, 596 (or 63%) had no patent policies (Palmer 1962). They typically dealt with patents on a case by case basis, in many cases simply referring patent matters to the Research Corporation, or had invention administration agreements with the latter. Even among the 20 largest universities discussed above, there was considerable variance in policies.[13]

Postwar Federal Policy Changes

In the postwar debate about the course of American science policy, one of the few things that the major factions agreed upon was the desirability of a single major funding agency. Despite

[13] MIT had the most comprehensive policy, requiring disclosure of potentially patentable inventions to the Institute, which would screen them and turn over promising inventions to Research Corporation.

Harvard, Columbia, and Hopkins left the decision to patent up to individual inventors. However, at each of these universities, patents on public health related inventions continued to be prohibited (Columbia and Harvard) or discouraged (Hopkins). In cases of sponsored research, these universities typically ceded rights to sponsors.

Chicago had a similar philosophy but stronger control over patenting activity. Patents were viewed as anomalies, which may arise in the course of research. However, neither the university or its staff were to own the patents or benefit from them financially.

The University of Texas and Stanford were laissez faire, leaving the decision to patent to individual inventors with few restrictions. Cornell, too, had a laissez-faire policy, except in the areas of medical inventions and inventions resulting from the New York State colleges, which were required to be reported to the University.

Among the Universities that still had research foundations that managed patents, there was also variety. Wisconsin had no patent policy. At the University of California schools, too, reporting of inventions to the Board of Patents was voluntary, except for faculty working on specially designated projects. By contrast, Minnesota, Illinois and Ohio State each mandated disclosure of patentable inventions and asserted rights to these patents.

this, the postwar R&D system was effectively characterized by numerous funding agencies, each with their own missions. A consequence of this was that the issue of disposition of intellectual property rights resulting from government funded research was decided on an agency by agency basis. The main difference across agencies was that certain agencies followed a "title" policy, whereby the government retained title to all sponsored inventions, and others had a "license" policy, leaving title with contractors and retaining a license for the government.[14]

By the 1960s, this lack of uniformity became cause of considerable concern. In an attempt to "rationalize" government patent policy, the Kennedy Administration released in 1963 a Presidential Memorandum which framed general guidelines that agencies should follow in formulating their policies. The Memorandum took a middle ground between title and license policies, noting that title policies were preferred unless the contractor had an established commercial position in the field. Implementation of the memorandum was left to the discretion of agency heads.

Though the Memorandum did not deal explicitly with universities[15], in 1964 the Department of Defense interpreted a "special circumstances" clause of it to mean that it could prospectively grant title to inventions to universities with "approved" patent policies, i.e. those which required faculty to report sponsored research and allowed for acceptance of patent rights on these inventions. The proposed argument for doing so was that in the absence of patent rights (which could be transferred via license) firms would not be willing to devote funding to develop university inventions. This policy change prompted many universities receiving significant Defense funding to attempt to change their policies to meet these guidelines. In many cases, they turned to Research Corporation for assistance in doing so.

Washington, Pittsburgh, Pennsylvania, Michigan, and NYU also asserted rights to all inventions made using university resources, and thus either explicitly or implicitly required disclosure of such inventions.

[14] In writing up the discussion of postwar policy changes, we have benefitted tremendously from Eisenberg (1996), to whom the reader is directed for a more detailed discussion. See also Mowery et al. (1999).

During the 1960s there was growing belief in the argument that absent university retention of title and permission to grant exclusive licenses, the fruits of government funded research would not be commercialized. This was based in part on "evidence" that rates of commercialization were higher when contractors (generally) retained title to inventions.[16] More specifically to universities, a study of the National Institute of Health's (NIH's) medicinal chemistry program concluded (based on their own appraisal of the evidence) that private pharmaceutical firms were unwilling to attempt to screen or otherwise develop university inventions without promise of an exclusive license from the university.

Allowing universities to retain title and to issue exclusive licenses seemed like an easy fix. A number of agencies began to consider case-by-case requests for title ex post, but universities complained that this was a time and resource intensive process. Thus in 1968 and 1973 respectively, the Departments of Health, Education and Welfare and the National Science Foundation, which (with Defense) were among the leading sources of federal academic research funding, allowed academic institutions to patent and license the results of their research under the terms of Institutional Patent Agreements (IPAs) negotiated by individual universities with each federal funding agency. IPAs eliminated the need for case-by-case reviews of the disposition of individual academic inventions, and facilitated licensing of such inventions on an exclusive or nonexclusive basis.

The Emergence of Technology Transfer Offices

These policy changes decreased the costs facing universities of getting more intimately involved in patent matters. The granting of IPAs and the tenor of the debates that led to them suggested growing support by policymakers of the position that patents were necessary for transferring technology from universities, and implicitly that without them, university contributions to economic growth would be compromised. This made it easier to reconcile involvement in patents

[15] This may explain why it does not explicitly deal with the possibility of not patenting research results at all.

with the implicit postwar contract that scientists (universities) had made with the government, to provide economic and social benefits in return for federal funding.

Prospective title was given to agencies only when they had approved patent policies and procedures. To aid in these efforts, (and in hopes of gaining access to a larger pool of inventions), in the mid-1960s Research Corporation began an extensive visitation program to consult on matters of patent policy and procedure. By mid-1970s, there were a number of conferences on matters of university patent policy and procedure, where university administrators as well as staff from places like Research Corporation and WARF shared collective experiences. The fact that a handful of prominent universities became active in this area about the same time made it less costly not only in the public eye, but also because they could learn from one another's experiences.

Another factor that led universities down this path was the realization of Research Corporation, by the early 1970s, that it could not efficiently manage the entire technology transfer office from screening to licensing, for each of the more than 200 institutions with which it had invention administration agreements. Thus, it began persuading its university partners to develop their own expertise in early stage screening and evaluation activities; it planned to focus on the patent prosecution and licensing stages of the transfer. Specifically, they argued that "[r]esponsbility for carrying out the procedures must be assigned unequivocally to an individual or an office in the administrative branch of the institution" (Marcy 1973, 5). In an attempt to assist them do so, it began an outreach program aimed at increasing awareness about patenting university research and its own activities in this domain.

Given that policymakers and the public were willing to accept university involvement in patent matters, once they got their feet wet in these hitherto forbidden waters, and developed some in house expertise, the marginal costs for universities to get more actively involved in technology transfer activities were considerably lower.

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[16] However, as Eisenberg (1996) points out, this evidence was in fact weak.

Moreover, the rise of new fields of science made the benefits of doing so high. During the 1970s biomedical technology, especially biotechnology, became an important and productive field of university research, and the results of research in that field were very interesting to industry. Beginning in the mid 1970s, universities knew if biotechnology discoveries were deemed patentable by the courts, substantial revenues could result.

Moreover, the fact that a key early discovery in biotechnology, the Cohen-Boyer technique, was developed in a university, was subject of a patent application, and was likely generate significant income, was important in focussing universities' attention on the possibility of revenues through patenting and licensing activity. Of course, the WARF Vitamin D patents had a similar effect earlier in the century.

Finally, unlike the earlier era when university inventions were few and far between, universities, especially those with significant academic medical school complexes, likely understood that the rise of biotechnology would lead to a more steady stream of inventions.

A number of universities were responsive to these changes in costs and benefits. Thus Table II shows that more and more universities began assigning employees to technology transfer beginning in the mid-1970s:

TABLE II HERE

As early as 1974, Research Corporation noted in its Annual Report that every major institution was considering setting up a technology transfer office. The 1975 Report notes that at a number of universities major inventions were no longer being turned over to Research Corporation, instead being administered internally by universities formerly involved with the Corporation.

We argued in an earlier paper with David Mowery and Arvids Ziedonis (Mowery et al., 1999) that even absent legislative action, these changes would have led to policy and organizational changes that induce the bundle of routines we refer to as a "technology transfer office". Indeed, by 1980, 20 such technology transfer offices existed, and many other universities were considering getting into the patent business.

However, there remained some uncertainty about whether these activities would continue. In particular, the implicit endorsement by the government that leaving title with universities facilitated technology transfer was tenuous, and not shared by all government agencies. Thus, by 1979 only NSF and HEW had created IPA programs, despite the 1976 issuance of a directive by the GAO that all agencies should do so. In addition, in the late 1970s HEW in particular began to voice concerns that blanket IPAs may not be prudent, and considered the virtues of shifting back to case by case assessment. Some universities complained about the difficulties they faced when attempting to petition for exclusive licenses.

These uncertainties were compounded by the fact that, dating back to a 1920 order by the Attorney General, agencies were not legally allowed to turn over title to contractors without legislative approval. Though agencies like DOD, HEW, and NSF had gotten around this via maintenance of "march in" rights, there was still considerable uncertainty about whether these would hold up in court if push came to shove.

In was in this environment that the Bayh-Dole Act was passed in 1980. Bayh-Dole legislatively created a uniform patent policy, under which universities with approved patent policies and procedures were allowed to retain the rights to government funded research and license these inventions on a non-exclusive or exclusive basis. More importantly, it was a strong Congressional endorsement of evolving belief that patents on university inventions are necessary to facilitate technology transfer. Testimony in favor of Bayh-Dole was offered by executives from pharmaceutical firms, representatives of WARF and Research Corporation, and university representatives. It was passed in a context where policymakers were concerned about American "competitiveness" and viewed the Act as a means to more effectively leverage federal research dollars for economic growth.

Also in 1980, the U.S. Supreme Court decision *Diamond v. Chakrabarty*, upheld the validity of a broad biotechnology patent, opening the door to patenting the organisms, molecules, and

research techniques emerging from biotechnology. This decision was at least as important as Bayh-Dole in encouraging "entry" into technology transfer by universities.

The Standardization of Mechanisms of Technology Transfer

Importantly, Bayh-Dole alone allowed for a reasonably roomy choice set. Unlike the early HEW and NSF IPAs, the Bayh-Dole legislation contained little in the way of exactly what was required in terms of university policy and procedures. In 1982, an Office of Management and Budget Circular clarified reporting requirements for universities: universities that wished to retain title were required to report inventions to the sponsoring agencies within 2 months of disclosure by inventors. Final rules and regulations were implemented in 1987 by 37 CFR 401.14. The "Standard Patent Rights Clauses". Under these rules, universities were required to establish a written agreement with all employees to disclose promptly each subject invention made under a federally sponsored program, to execute all papers necessary to file patent applications, and promptly report inventions to the sponsoring agency.

Despite these degrees of freedom, by the early 1990s, virtually all major research universities had adopted broadly similar routines in this area. Since 1980, we have seen the number of technology transfer offices grow from 25 to over 200. Membership in AUTM grew from 150 in 1984 to over 1500 today. Technology transfer offices were established: most are centralized, though at some schools, like Johns Hopkins and the University of California, different offices serve different campuses. These offices are charged with evaluating inventions, filing for patent applications, and licensing patents. According to a recent report, the new offices are fundamentally different from their predecessors:

> The skill mix has changed as well. In 1984, the majority of university tech transfer offices were staffed by a]one patent attorney. A decade later, these offices have been taken over by a combination of professionals with backgrounds in marketing, business development and scientific specialists (Levine 1995, 60).

University intellectual property policies state that under terms of employment, universities, rather than the inventors, retain title to any intellectual property resulting from faculty research. Universities thus require that faculty report to the technology transfer office all inventions potentially patentable inventions and research results, via forms known as "invention disclosures". If the technology transfer office decides not to accept the invention, the university releases all rights to the inventor. If the technology transfer office accepts the invention, then it decides on whether to patent the invention, and terms of licenses with firms. Any royalties that may result are divided between the university, the inventor, and in cases the inventor's lab or department, as specified by the sharing rule in the university's intellectual property policy.

Potential licensees deal with the technology transfer office rather than the inventor directly. Thus, unlike an earlier era, all university-industry cooperation that may involve patents must be coordinated by the technology transfer office. Moreover, these institutions are not shy about their business orientations: there is little in the way of reluctance to file exclusive licenses or to appear to be profiteering.

To tie together these strands, let us recap how *this particular bundle* of social technologies emerged, and what forces led to their standardization. The technology transfer office has as its predecessors the university research foundations and the Research Corporation, as well as the examples of a handful of universities like MIT and the University of California that were more centrally involved in technology transfer well before Bayh-Dole.[17] Some universities turned to these examples when they were required, to qualify for HEW and NSF IPAs in the 1970s, to demonstrate competence in technology transfer. In addition, as we noted above, beginning in the early 1970s Research Corporation had been encouraging universities to become more actively involved in the early (evaluation and screening) stages of technology transfer, and indeed had

[17] MIT's relationship with the Research Corporation was terminated in the 1960s over a dispute over Jay Forrester's magnetic core memory patents. At that point, MIT essentially began performing in-house many of the services that it had previously contracted out to Research Corporation.

been teaching them how to do so. An unanticipated effect of compelling universities to invest these fixed costs was to make the costs of conducting the entire operation in-house much lower. The technology transfer office was thus in part simply an internalization of activities which the universities had previously contracted for with Research Corporation.

Bayh-Dole per se did not prescribe what type of organizational arrangements were required. However, through its effects on expected costs and expected benefits of becoming more involved in technology transfer, it did provide incentives for universities to become more involved in patenting and licensing. In response, universities began to set up internal technology transfer offices, sticking closely to the design that had emerged in the 1970s. This emulative tendency reflected not only disutility from nonconformity, but also bounded rationality (not a broad and well-defined choice set) and the network externalities based largely on the ability to benefit from shared social learning.

The policies were standardized through a similar mechanism. The DOD requests for waiver and the NSF and HEW IPAs in the 1970s did prescribe fairly specific policies: basically, that universities must assert rights to all government funded inventions. Though the Bayh-Dole act did not specify what types of policies must be enacted in order for universities to retain title, in response to the incentives created by Bayh-Dole, universities did change their policies to take title to inventions. Again, there were pre-Bayh-Dole examples to which they turned. Interestingly, most policies today assert rights not only to government sponsored inventions but to all faculty inventions, a point which we will return to below.

There is some variance in the specific procedures followed by universities in regard to disclosure requirements and sharing rules, though the broad outlines of these too are standard. (Part of this reflects the fact that Bayh-Dole and the regulations which implemented it were reasonably specific on the type of disclosure system needed and on the need for a sharing rule.)

However, typical ways of dealing with inventors, writing license agreements, and negotiating with licensees were standardized in a different way. These drew on the collective

experiences of technology licensing officers. Part of this knowledge is disseminated via publications and conferences of AUTM, the Association of University Technology Managers, a society which assists members in the management and promotion of academic technology[18], and of other groups including Les Nouvelles and the Technology Transfer Society. There exists an active internet mailing list, techno-l, where university technology transfer officers exchange experiences. Such groups help to disseminate knowledge of "best" practice procedures.

Indeed, the preceding paragraphs should make clear that though the basic ways in which technology transfer offices operate are standardized, there has over the last years been gradual change in what is considered generally accepted practice. Thus, university policies have come to assert rights and thus require disclosure of all faculty inventions, rather than only those that are government funded. There are fears that even the notion of an "invention" has shifted, with universities increasingly attempting to patent and license research that is more aptly characterized as science--and would have in an earlier era simply been published--than technology. Additionally, technology transfer offices are increasingly involved in software and new media, areas which are typically covered by copyright rather than patents. Finally, the justification is no longer simply that these activities facilitate technology transfer alone, but also that the universities have a right to any profits that result from faculty work.

In the midst of this, there has been little empirical analysis of the social benefits of the new social technology. Typically, university administrators and groups like AUTM point to growing level of patents, licenses, and revenues as evidence that the new regime is working, with the implicit (and perhaps heroic) assumption that these metrics are somehow related to gains social welfare. Interest groups have formed--like AUTM, university administrators and technology transfer officials, and pharmaceutical companies--that have a vested interest in its survival. A perusal of the techno-l mailing list or leafing through an AUTM publication suggests

[18] Indeed, much of the data used to support the argument that the Bayh-Dole act is working is based on surveys conducted by AUTM.

that a norm has developed among these parties that this is the "right" (not only "expected") way things are done. That is, social technologies can take on lives of their own.

Despite a lack of clear evidence, policymakers appear to believe that the new regime is working (see e.g. United States Government Accounting Office, 1998) and attempting to adapt it to different contexts, e.g. to national laboratories. Even smaller universities, perhaps without the research base to make it profitable--are increasingly employing this social technology. In addition, foreign governments (e.g. in Canada and Japan) are looking to the new American "system" of university-industry technology transfer an example. Thus this social technology may well diffuse further.

V. Reflections on the Emergence and Standardization of Social Technologies

Based on the case study above, in this section we reflect on institutional emergence and change. We recognize that some of the forces and mechanisms that we focus on are likely to be idiosyncratic to the case at hand. Indeed, just as there are important differences by class of technology (and by industry) in dynamics of how physical technologies change, different "types" of social technologies emerge, change, and are institutionalized through different mechanisms. In future work, we intend to draw out a taxonomy of these differences across "types" of social technologies, as well as to consider in greater detail the extent to which analogies can (and cannot) be drawn between the emergence, change, and standardization of physical and social technologies.

The preceding should make clear that this is not a full-blown theory of institutional emergence, institutionalization, or institutional change, but rather a progress report about our thinking on these matters as evidenced in the case study above, from the vantage point of Nelson and Sampat (1999).

We begin by reflecting on the emergence of the social technology that we have dubbed the "university technology transfer office" in the mid-1960s. Is it really a "new" social technology? Certainly there were important precedents to the technology transfer office per se as well as the mode of interaction with industry, albeit with different organizational set-ups and incentive structures, e.g. in University Research Foundations (like WARF) and in patent management agencies like Research Corporation. As we have suggested above, these too had important precedents that they borrowed from. This social technology was also induced in part by changing university patent policies and procedures, which were also based on precedents at universities and agents like the Research Corporation. It may thus be better to view to social technology not as new, but rather as the recombination of components of older packages of routines. This is also often true of new physical technologies (see e.g. Nelson and Winter 1982; Usher 1929; Rosenberg 1976).

This can also be said in the importance of emulation and precedence as leading to standardization. Many institutionalists have pointed out that evolution of "the rules of the game" e.g. of the common law, relies heavily on precedent. Here we suggest that that is also true of the social technology employed. (Though the latter may at first glance appear to be more like the "way the game is played" than the "rules of the game", in Nelson and Sampat 1999 we suggest that from a social technologies as routines point of view, these distinctions are blurry.)

Precedent is important for a number of reasons. The first is that human choice sets are bounded, and the relevant "routine-possibility space" over which actors choose is typically limited to items that have been tried or at least observed. A second factor that is particularly strong in this context (but is likely not in others) is that universities did not want to deviate too far away from the "ideal type" of a university, which, as we discuss in greater detail below, is itself a broader institutionalized collection of routines. Unorthodox modes of behavior can, in certain contexts, provoke hostile reactions. The more common the new mode becomes, the less sharp the negative reaction. A third factor is that by adopting a social technology that is similar to one that

has been observed in practice, one can draw on social knowledge. As with new physical technologies, there is often considerable uncertainty about how to implement new social technologies or how well they might work in a particular context. Sticking close to a bundle of routines that has been seen as working reasonably well allows one to learn from the experiences of others. On the other hand, avoiding those which have known pitfalls is also part of social learning: recall that according to Fishman (1996), MIT originally chose to contract with Research Corporation, rather than go at it alone, partially because of the negative publicity that surrounded WARF at the time. For the evolution of social technologies, as with physical technologies, the results of even failed experiments are useful.

Of course, the factors that promote mimicry are among the forces that lead to and sustain standardization of social technologies The importance of the MIT agreement to Research Corporation was in part because it attracted other universities, and this was a snowballing mechanism. Thus though a number of other approaches were tried by research universities in the immediate postwar era, the "contract with Research Corporation" routine become the de facto standard from the mid-1950s to the mid-1970s. Similarly to dominant designs with physical technologies (Utterback 1994) this standardized mode of behavior was also sustained through a number of other positive feedback mechanisms, including most prominently the fact that as the relevant actors--university faculty, administrators, firms, and granting agencies--became used to working in these ways, kinks were worked out, complementary assets, skills, and routines developed. Similarly, after the technology transfer office model was adopted by a sizable number of universities in the late 1970s and early 1980s, government agencies set up compliance mechanisms, firms (especially in pharmaceuticals and biotechnology) set up search routines to work with those of the universities. If we view the costliness of a routine as a function of how well it coordinates and/or meshes with routines of other actors and organizations, then standardized social technologies can be thought of as "low transaction cost" ways of proceeding. These forces made the "technology transfer office" routine that much more attractive to other

universities. The need for coordination within systems of routines is another theme that has analogs in the literature on standardization of physical technologies (see e.g. Arthur 1994).

On a related point, standardization is also supported by the process of collective learning. Indeed, that is why standardized social technologies are, and can increasingly become, low transaction cost ways of proceeding. We have noted that before universities began becoming centrally involved in patenting and licensing, the common mode of behavior was to leave these issues--in the rare cases that they arose--to inventors or to sponsoring firms. Though we have little evidence on this matter, we conjecture that the parties to these transactions--firms and university faculty--developed and honed their routines through looking to the experiences of others.[19] We observed that in the 1970s, when universities became more involved in petitioning for IPAs and administering resulting patents, and setting up nascent technology transfer offices, experience was shared via conferences and via associations like the Society of University Patent Administrators and that today groups like AUTM and techno-l play a similar role.

In the preceding paragraphs, we have considered the forces that lead to the emergence of new social technologies and to the standardization of social technologies. What about the more general question of how and why standardized social technologies change, or are replaced by new social technologies? Like many institutionalists, we view the routines that are employed by actors as responsive to changes in economic costs and benefits, albeit usually imperfectly and often with a lag. However, for reasons we flesh out below we view it as unhelpful, and often downright wrong, to think of institutional change as being an "optimal" response to changes in costs or benefits.

We observed that the early entry of universities into handling of patents and licenses, by Toronto and Wisconsin, was prompted by "exceptional circumstances" (specifically significant patents) that dramatically raised the benefits of doing so. Consideration and formulation of

university patent policies and was prompted by the growth of industrially research contracts in the 1930s and, to a much greater extent, by the dramatic growth of government sponsored research in the post WWII period. The rise of biotechnology, and also the significant revenues in this area that California and Stanford were expected to earn, also led universities towards adoption of technology transfer routines in the 1970s. The Bayh-Dole act made the latter option more attractive by reducing the cost of adopting this bundle of routines. (As we point out below however, this was not the only, nor necessarily the most important, effect of Bayh-Dole.)

These examples illustrate that that the emergence and evolution of new routines were indeed responsive to changing costs and benefits. However, we have already noted that the relevant choice sets are constrained by what variants of what has already been observed or practiced. In cases, changes are not made, because there is very little in terms of useful precedent to replace extant social technologies. In others, in response to changing costs and benefits, new routines are brought into a context when they do not mesh with other physical and social technologies. (Thus a number of smaller universities have set up technology transfer offices that mimic those of larger schools, and it is unlikely that these are yielding significant benefits to former. We conjecture that there may be some reconsideration of this model in these contexts in the future, but there are little signs of it yet.) Institutional evolution is thus path dependent, and it is misleading to think of the responses of actors as being "optimal" (see also North 1990).

This raises another important point. Social technologies employed for any one specific end are typically parts of larger packages of physical and social technologies, i.e. parts of a broader constellation of routines. An important inducement mechanism for change in a social technology can be changes in complementary routines. Thus in the midst of the growth of industrially funded research, land grant schools needed a mechanism to coordinate industrial relations. Once this social technology was set up, the marginal costs of incorporating it into a

[19] We observed above that in the 1920s, university faculty members with patents or patentable inventions turned to Research Corporation, more than a decade before it established a patent

university research foundation which also handled patents was low. Similarly, once universities dealing with Research Corporation began taking responsibility for the early stages of technology transfer, the marginal costs of bringing the whole operation in-house became significantly lower. This institution itself has been the impetus for change in complementary routines: Major universities like the University of California are today beginning to assert ownership of copyright to online courses. Moreover, the fact that this will impact the "teaching" routines of the universities is an unintended consequence of the new social technology that was not anticipated. These examples suggest that changes in complementary routines, by changing costs and benefits, can thus also be an important impetus to institutional change. Again there are analogs in the realm of physical technology: Rosenberg (1969) discusses the importance of technical imbalances between complementary routines in focusing exploratory activities in particular directions.

Finally, we touch on the issue of whether the social technology we observe in practice today is best thought of as "consciously planned" or "spontaneous". We have argued that this mode of interaction began in the 1970s, well before the passage of any legislation. The mode of interaction that had evolved by the late 1970s was the result of uncoordinated and decentralized interaction by various actors, including most prominently universities and government agencies. These actors obviously made deliberate choices. But in doing so, they also gave credence to the notion that this was an acceptable way of doing things, an unintended aggregate outcome. However, as we indicated in the case study, there remained considerable uncertainty about whether this mode was "acceptable" and would be allowed to continue. The state, via the passage of Bayh-Dole, expressed a strong endorsement of this mode of behavior. Together with the concurrent court decision, *Diamond v. Charkrabarty*, Bayh-Dole represented a collective stamp of approval on this mode of behavior, and in doing so also solidified expectations that it would be allowed to continue. Note that this is consistent with John Commons's (1924) view that while "working rules" (similar to our conception of standardized social technologies) can arise in an

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management division, because of its successes in managing Cottrell's precipitation patents.

uncoordinated spontaneous fashion, collective action via courts and legislatures is typically necessary to solidify such modes of interaction.

We conclude by noting that there has been some skepticism about the social welfare impact that the standardized social technology currently in practice. There are some concerns that it is displacing some of the modes of behavior associated with "open science" by fostering secrecy and commercialism (e.g. Nelkin 1984). This is disquieting, if not in itself, then because the open science model is thought to be a primary reason why research universities have been so important in the process of economic growth (Dasgupta and David 1994; David, Mowery, and Steinmueller 1992). This is especially so since there is little evidence that the theory underlying it--that patenting and marketing of university inventions is necessary to reap the fruits of public investment in research--is valid for all classes of "inventions" (Nelson and Mazzoleni, 1996; Mowery et al 1999). Indeed, with the exception of pharmaceuticals and biotechnology, few industries view patents and licenses as important mechanisms of technology transfer (Cohen et al, 1999). However, the social technology has been applied wholesale, to all departments in the university. This has caused some tensions: for example, Columbia's engineering faculty opposed the new rules and procedures, questioning their utility and fearing that they would impede the modes of working with industry that they had already established. Again, this illustrates the necessity of tailoring particular social technologies to complementary routines in place, which are likely to be different across fields and departments. Finally, and related to the first point in this paragraph, there are some fears that the new regime is beginning to encroach on scientific research, as well as inventions, another context in which it does not promote social welfare, though it may be privately profitable for universities (Eisenberg 1996; Mowery et. al. 1999). Again, social technologies, once standardized, can take on a life of their own.

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Table I: Research Corporation Invention Administration Agreements, 1946-1956:

1946	6
1947	10
1948	17
1949	24
1950	37
1951	44
1952	52
1953	60
1954	75
1955	83
1956	89
1957	97
1958	103
1959	112
1960	122
1961	134
1962	140
1963	159
1964	175
1965	183
1966	189

Table II: Absolute Frequency Distribution of First Year in Which AUTM Universities Assigned >= .5 FTEs to "Technology Transfer" Activities

1921-25	1
1926-30	0
1931-35	1
1936-40	1
1941-45	1
1946-50	1
1951-55	0
1956-60	1
1961-65	0
1966-70	3
1971-75	4
1976-80	10
1981-85	24
1986-90	41