# INTO THE FRAY:
# SHIFTING FACTORS AFFECTING THE DIFFUSION OF COMMERCIALIZED SCIENCE IN HIGHER EDUCATION

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Kelly Lee Patterson

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ABSTRACT

Universities have resisted commercializing technology for the greater part of this past century. Until recently, only a small number of universities transferred their technology to the public, but now commercialized science is widespread. This study explores how the field grew and how different factors affected the diffusion of this once illegitimate practice over time. Specifically, this study investigates the adoption of technology transfer offices – university employees committed to facilitate the transfer of university technology for commercial use – and how universities' status, identity, and exposure to prior adopters differentially motivated their engagement in this activity over time.

# BIOGRAPHICAL SKETCH

Kelly Patterson was born and raised in Sterling, Virginia on June 5, 1970. In 1992 he graduated from The Citadel in Charleston, South Carolina, where he studied business administration and modern languages. From 1992 to 1998, he served as an officer in the United States Marine Corps, where he earned the rank of Captain. Following this, he attended the Ohio State University in Columbus Ohio, where he received a Masters Degree in Business (MBA). After graduating, he worked as a management consultant, where he advised corporations in the high tech manufacturing industry. In August of 2003, he moved to Ithaca, New York to begin graduate work in Organizational Behavior and Sociology at Cornell University.

*For my mother*

*In fond memory*

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# PREFACE

Universities have resisted taking steps to commercialize their own technology for the greater part of the past century. Until recently, only a small number of universities were involved in the commercial transfer of technology they developed to the public. Less than 10% of major research universities adopted offices to commercialize science before 1980. Commercialized science became more widespread in the following years, however. The majority of major research universities established a technology transfer office by the turn of the 21st century, the number of commercial agreements executed between the university and industry increased from 1,148 in 1991 to 3,606 in 2000 (Association of University Technology Managers [AUTM] 2001), and in the life sciences and in many engineering fields, university science displaced a great deal of private research and development activity in industry by the late 1990's (Owen-Smith 2000).

Prior research on university technology transfer activity has examined both recent university licensing performance (Mowery et al 2001, Sine et al 2003) and the impact that commercialized science on the academy's culture (Campbell et al 1996). Little attention has been paid to the process by which the field grew – how universities emerged as principal engines of invention and economic development in the US (see Owen-Smith 2003). This paper fills the gap, exploring the commercialization of research in higher education by examining the process by which technology transfer offices (administrative offices commercializing university technology) diffused.

This study is not only substantively unique, but it is also different from most accounts of diffusion. The majority of this work has focused on the rational decision-making of potential adopters without exploring how context affected the speed and direction that a practice spread. Among the studies that have explored context, there has been a bias toward cases where diffusing items had a normatively prescribed status -- rather than a proscribed status. In this paper, the diffusing practice -- the technology transfer office -- held an illegitimate status as it started to spread through the population. It did not accord with the cultural understandings of appropriate action (Strang and Soule 1998) as it began to diffuse through the field. Practices rarely spread through a normative vacuum, and in the field of higher education, the commercialization of science that the technology transfer office represented was particularly offensive to many academics in the 1970's (Slaughter and Leslie 1997). The pursuit of science for profit, while potentially lucrative, represented an approach to university science that conflicted with the basic science orientation in the field at the time (Merton 1973).

Structures that do not battle such stigma tend to spread through a population based on their own merits (Teece 1980) or get pushed through a population through social influence and bandwagon pressures (DiMaggio and Powell 1983). Practices that are illegitimate are slowed by cultural resistance and diffuse across a population as cultural barriers detracting actors from adopting begin to fail. Using 1972 to 2000 data on university characteristics and adoptions, I show how both status and identity at the individual level and safety-in-numbers at the population level helped to counter and erode these barriers. This research goes on to show that there was a shift from individual-level to population-level factors over time. These findings help sharpen one's understanding of technology transfer management in the US and help illuminate the temporal connection between multiple factors and the adoption of structures whose legitimacy is open to question.

# CHAPTER 1

# DIFFUSION LITERATURE

There have been two major streams contained within the contemporary literature on inter-organizational diffusion. The first stream, built on the rational actor model (Strang and Macy 2001), has been the most "diffuse" perspective in the diffusion literature (Rogers 1995). This stream has focused on choices motivated by technical factors -- factors that affect efficiency -- and have assumed that the relative efficiency of a practice is the primary driver of adoption speed. Such models are attractive in their relative simplicity and generalizability across a diversity of contexts. However, students of diffusion have been easily dissatisfied with the dearth of attention paid to social context in these accounts. Eager to explore a more realistic, comprehensive set of mechanisms that do take social context into account, a second stream of research has emerged. These "social" models - alternatively called "contagion accounts" (Strang and Macy 2001) or "institutional perspectives" (Jonsson 2002) have explored non-technical factors influencing the motivations and decision-making capabilities of organizational decision-makers. In this section, I divide the diffusion literature into the two essential metatheoretical perspectives, and then I highlight a subset of the "social" perspective which has explored the diffusion of illegitimate practices.

## *Rational Accounts*

Most accounts of diffusion have assumed that organizations are motivated to ensure their continued growth and profitability by adopting practices and structures that are singularly cost effective and optimize the transformation of goods and services (Chandler 1962; Armour and Teece 1978; Teece 1980). This explanation has its roots in the economics literature, which has assumed that actors are inherently rational, are self-interested, and take the most direct action to pursue their goals (Williamson 1979). This "rational" view is not unlike the earliest depictions of managers in the organizations literature -- organizational engineers, whose decisions and fate were tied to arrangements that ensured predictable, reliable, efficient activities in the pursuit of collective goals. Rational accounts favoring this mechanical image are intuitively appealing, as they focus on the presumed economic benefits that result from the adoption of a practice (Teece 1980), and associated models are powerfully predictive and elegant in their simplicity, despite their limited complexity and realism. Critics point out that these accounts typically fail to consider social context, which serves to constrain the adoption choices actors make (Zucker 1987; Ingram and Clay 2000). As Ronald Coase (1998, p.73) suggests, these accounts can be likened to the larger body of work on decision-making in economics, which studies "the circulation of the blood without a body."

This limitation is difficult to ignore in light of the most recent research on practice diffusion, which has demonstrated that inefficient practices diffuse in a population of organizations (e.g. Abrahamson 1991; Mitroff and Morhman 1987; Soule 1999) and that efficient practices often stall (Ahmadjian and Robinson 2001; Soule 1999). The concept of "efficiency" is more complex than assumed by core rational accounts; this is a theme that has been explored in a second stream of studies, which Strang and Macy 2001 call "social" accounts.

***Social Accounts***

While rational accounts conjure up the machine-like images of the organization – efficient in both its means and ends -- a separate research stream captures the essence of the organization by suggesting a more biological metaphor. Such an image suggests that the livelihood of an organization, like a living organism, is influenced by interactions with its environment. The organization gains access to resources, which include raw material, human capital, finances, and knowledge - even social approval --through these ties. Like a living organism, the organization depends on access to these resources in order to sustain its life. While studies that invoke this image do recognize that organizations face technical pressures from the environment and are expected to provide goods and services through markets or exchanges, they also assume that expectations are often focused on the means of production, as well as on the ends. In many complex, socially embedded contexts (Granovetter, 1985), the public expects that organizations will assume broader societal roles or operate within the boundaries of predetermined rules and values, where an organization's choice of structures and practices is often prescribed by actors and agents outside the organization (DiMaggio and Powell 1983; Scott 1995).

Most "social" accounts of diffusion rest within this framework and focus on both the gradual institutionalization of innovative practices within a population and the subsequent obligation organizations have to adopt these methods as they reach a taken-for-granted status. The emphasis in these analyses is typically on the limited agency organizations have in the face of these prescriptions and the relative legitimacy organizations possess as they either conform or fail to do so. These accounts often present cases where a diffusing practice is suboptimal -- less-than-efficient in solving its stated goal. However, due to factors other than efficiency, such as the growing awareness of the normative expectations of outside stakeholders or bandwagon pressures (DiMaggio and Powell 1983; Abrahamson 1991), members of a population of organizations grow to accept this practice.

The key mechanism at work here is imitation. Organizations pattern their behavior after their peers -- particularly highly visible and successful peers -- accepting the number and status of prior adopters as signals of the appropriateness of a practice. Such a mechanism relaxes assumptions regarding the agency of actors, replacing rational self-interest with group pressures and assumptions about appropriateness as decision-making drivers. Both rational and social accounts do describe the diffusion process in terms of the efficiency, albeit in different ways. "Rational" adoption of practices is driven by a desire to improve efficiency, while "social" adoption is motivated by the desire to appear in conformance with norms (Meyer and Rowan 1977; DiMaggio and Powell 1983; Scott 1995; Zucker 1977).

***Normative Fit***

By highlighting the role of "context", social accounts add a dimension to the diffusion story left out by most rational accounts. Despite this contribution, however, at times these social accounts assume that practices spread without normative contestation (see Tolbert and Zucker 1996). Not all diffusing practices are "neutral"; rational and social accounts alike tend to overlook the fact that many practices come loaded with implicit worldviews that are not consistent with incumbent contextual values. In some cases, particularly where diffusion occurs in highly-institutionalized fields, the illegitimacy of a practice is an important factor that affects its ability to diffuse through a population (Strang and Meyer 1991; Strang and Soule 1998).

Fortunately, authors are increasingly aware of the fact that diffusion processes are embedded in systems where ideas and norms exert a strong influence over the likelihood of adoption (Starbuck 1982). Such authors show that illegitimate (normatively inappropriate) practices are slow to diffuse across a population. Hirsch's (1986) study of hostile takeovers in the US was one of the first of these studies, showing that an illegitimate business strategy was slow to diffuse until normatively framed as a neutral rather than deviant practice. This study shows that cultural compatibility, rather than the social structure among actors, led to the eventual integration of this practice within the system. As the language used to describe the practice softened, the stigma attached to the practice lifted. Similarly, Ahmadjian and

Robinson (2001) showed that public pressure to avoid an illegitimate practice slowed down its spread. They showed that in Japan, where permanent employment practices were institutionalized, layoffs were criticized. This public criticism constrained the diffusion process, despite perceived economic benefits.

The main theme in these studies is that practices upsetting the normative order are less likely to diffuse (Katz 1999: 150). This represents a slight shift in focus, given the theme in most social accounts. Most studies draw attention to the social (typically non-economic) benefits associated with practice adoption; the more institutionalized a practice, the more likely a potential actor will adopt it. Cost here is simply opportunity cost --- cost associated with non-adoption. Failure to adopt reduces an organization's standing in the eyes of constituents and jeopardizes ties to key constituents (DiMaggio and Powell 1983; Pfeffer and Salancik 1978). Studies of illegitimate practices, however, focus on the social cost of adoption – standing and social ties -- when actors do adopt. The more this social cost stands as a barrier to adoption, the lower the rate of diffusion.

Adoption here involves normative deviance – normative avoidance rather than imitation and compliance. Authors describing this behavior tend to highlight the mechanisms underlying defection, which differs significantly from isomorphism (Ahmadjian and Robinson 2001). Particularly, they tend to draw attention to cases where normative pressure fails to distance actors from normatively inappropriate practices. In some cases, failure can be attributed to indifference – an inherent lack of concern for the social cost of deviance. Leblebici et al (1991), for example, showed that actors outside the mainstream are often the first to adopt unconventional practices, particularly when these practices provide idiosyncratic value to them. Fringe radio stations in this study were the first to introduce radically new formats, finding they realized unique value from these practices. An earlier review by Menzel (1960) also highlights this form of defector. Here he points out how actors with little to lose are often the first to adopt innovations that deviate from existing norms. Using examples from medical and farming studies, he highlights cases where marginal actors -- actors only loosely integrated within their communities -- are less averse to crossing legitimate boundaries, particularly when these innovations are technically superior.

In the case of actors who are more sensitive to public criticism, however, a reduced sense of vulnerability comes from different sources. One such source could be a cognitively-appropriate public identity. Here, an activity denied to some might "make sense" when adopted by certain others. Recent work in organizational behavior has begun to base organizational classifications and categories on substantive interpretations -- characteristics that outside stakeholders use to classify an organization within its context (Hsu and Hannan 2005, McKendrick and Carroll 2001). Here, actors outside the organization apply cognitive frameworks to define legitimate forms and form the basis for social approval (Hsu and Hannan 2005). Zuckerman (1999) calls this sorting process the "categorical imperative" -- outsiders base their approval on a discrete set of cognitively legitimate characteristics. This process implies actors inside the protective boundary of legitimate identity are relatively free to behave in unconventional ways, as long as this behavior "fits" their identity (Edelman 1992, Rao and Sivikumar 1999).

Protection behind peers, rather than identity, is more typically the mechanism driving the adoption of illegitimate practices by more conscientious actors. Strang and Meyer (1993) unpacked this kind of cultural-cognitive process. They explained that, when diffusion processes did not unfold naturally -- when a practice was under-theorized and had poor cultural fit -- potential adopters needed to find support among prior adopters. Similarly, Davis and Greve (1997) found that the public illegitimacy of a certain corporate takeover strategy -- the "golden parachute" -- forced the practice to spread slowly. They found that, while the pattern of diffusion for the more legitimate "poison pill" strategy indicated contagion or bandwagon behavior (it diffused through relational ties), the illegitimate practice required local protection to spread. Under the umbrella of prior (geographically) local adopters, subsequent "golden parachute" adopters felt protected from public stigma and criticism. Here, population-level rather than individual-level factors helped actors overcome cultural barriers. and Rowan 1977; DiMaggio and Powell 1983; Scott 1995; Zucker 1977).

***Shifts in Causal Effects***

Cases such as the spread of corporate takeover practices in Davis and Greve's (1997) analysis represent a promising direction in diffusion research design. As Strang and Soule (1998) point out in their review of diffusion literature, more work needs to be done to compare diffusion rates and mechanisms across time and space. One such temporal case is Tolbert and Zucker's (1983) analysis of shifts in factors affecting the diffusion of civil service reform in the US. They demonstrate how contagion took over in across a population, showing how rational forces gave way to isomorphism over time. Similarly, Burns and Wholley (1993) found that as more and more hospitals adopted the M-form administrative structure, internal characteristics gave way to local bandwagon effects. Meyer et al (1992) and Collier and Messick (1975) also showed a shift from individual to population-level factors affecting diffusion rates over time.

A handful of authors have shown that causal effects also shift over time during the diffusion of illegitimate practices. Ahmadjian and Robinson (2001), for instance, found that the rate of corporate lay-offs among businesses in Japan grew higher as the number of prior lay-offs increased. Unlike the contagion examples given above, these authors witnessed the emergence of "safety in numbers" over time -- the same mechanism supporting the diffusion of golden parachutes. The Ahmadjian/Robinson model of illegitimate practice diffusion was actually a reversal of the Tolbert/Zucker (1983) model. Tolbert and Zucker found that, in in the absence of an existing, highly institutionalized arrangementrational factors gave way to legitimacy as determinants of the adoption of an innovation. In contrast, Ahmadjian and Robinson found that rational, efficient motivations for downsizing in a highly institutionalized context became powerful only after the process of legitimation. Leblebici et al (1991) revealed a similar temporal change in diffusion factors in a highly institutionalized context. They showed that the status of the actor was the most significant factor affecting diffusion rates of unconventional radio innovations early on. Adoption among marginal, indifferent actors gave way to adoption by mainstream, central actors as the diffusion process unfolded.

In this paper, I also study shifts in causal effects during the diffusion of a normatively inappropriate practice. Building on the literature above, I show how rational factors emerged over time as different social factors – first individual-level then population-level – led normative pressure to fail. The story of how these different factors affected the status of this diffusing practice in the US starts with a description of the landscape across which it spread.

## CHAPTER 2

## CONTEXT

The field of higher education in the US over the last few decades is well-suited for the study of the diffusion of a structure identified with an illegitimate practice. A more complete understanding of the diffusion of such a structure requires an understanding of the shift in the status of its associated practice; among research universities in the US, we bore witness to this process unfolding. Different factors can affect the legitimacy of a practice, and higher education provides an excellent setting in which to study these factors and how they shifted over time, differentially affecting the speed of diffusion across different sets of actors. Here we see how status, identity, and prior adopters affected the acceptance of commercialized science – a process that opened the door for filed-wide adoption of technology transfer structures.

### *A New Practice in Higher Education*

Despite a long history of practical research among US research universities, the contract-based technology exchange process – what campus administrators call technology transfer (AUTM 2002) – has become widespread throughout the field only over the last 30 years. It wasn't until the 1970's that the process of patenting and licensing research started to emerge as more than simply a peripheral practice. Before this time, ties to industry involved mostly training (e.g. students prepared for industry), publication (e.g. papers and books for use), and consultation (e.g. business consultation by faculty).

Commercial agreements between universities and industry did exist as far back as the 1800's (Rosenberg and Nelson 1994), but the systematic commercialization of campus-developed technologies through formal structures is a relatively new phenomenon within the field of higher education (Henderson, Jaffe, Trajtenberg

1998). Only 96 U.S. patents were granted to research universities in 1965. Nearly 2,500 were awarded in 1997 (AUTM 2002). While most universities had resisted direct involvement in commercialized science only thirty years earlier, by 2000, technology transfer had become a $1.1 billion business for higher education institutions (Mowery et al 2001). In fact, now over half of all top research universities have established technology transfer offices with full-time patenting and licensing professionals (AUTM 2002), codifying their entry into the "realm" of commercial science (Owen-Smith 2000).

Commercialized science was once taboo in the university; now, professionals in technology transfer offices are permanent fixtures on many campuses, coordinating intellectual property issues and bridging university activities to commercial sectors (Hirsch 1972; Castilla et al. 2000). Hired to promote commercially-appropriate science and to connect research community with relevant industrial partners (Owen-Smith 2000; AUTM 2002), technology transfer professionals are formally trained in science, law, and marketing and serve to facilitate tacit knowledge flows and trust-building between the university and its customers (Owen-Smith 2000; Feldman et al. 2002). The impact that these professionals have made on university ledgers is yet unclear, but there is no doubt that the establishment of a technology transfer office is the mark of a university eager to sell its science (Rahm 1994, Rogers et al 2003).

***Resistance to Commercialized Science***

Before the widespread commercialization of university technology, connections between universities and sectors that used their research were under a different regime. Market exchange through these industrial ties was rare, as most scientists believed that the proper mission and role of the university should be centered on basic science and service to society (Feller 1990). Professionals in the field of higher education thus discouraged an entrepreneurial orientation, believing that "academic capitalism" (Slaughter and Leslie 1997) - efforts to secure external funds through market-like behavior - would have the long-term effect of shifting research agendas, culture, and academic career plans and prospects away from the aforementioned mission and role (Etzkowitz et al 1998). Many faculty members themselves expressed the fear that uncontrolled commercial ties to industry would lead to conflicts of interest, secrecy, and the loss of the university's reputation for objectivity (Bok 2003). Often, scientists openly resisted commercial activity, basing this criticism on associated problems that included competing faculty priorities, delays in publishing due to patent process interference, and the reluctance by colleagues to share findings that could lead to a profitable discovery or scientific findings already under contract (Blumenthal et al. 1996). As Stanley Cohen of Stanford, who with Herbert Boyer of the University of California at San Francisco created the first recombinant DNA clone, recalled, "My initial reaction to (patenting and licensing) was to question whether ... research of this type could or should be patented and to point out that our work had been dependent on a number of earlier discoveries by others . . . no invention is made in a vacuum and inventions are always dependent on prior work by others" (Etzkowitz and Webster 1995, p. 489). One of the most widely-cited cases of outspoken resistance has been that of former Harvard University President Derek Bok, who warned to the school's Board of Overseers that "(f)lashing yellow lights should appear, however, whenever the institution seeks to make a profit on basic academic functions ... such as ... research ... in order to finance its other activities" (Bok 2001).

A major piece of legislation was passed in 1980 that put pressure on these resistors. In 1980, the Bayh-Dole Act was passed by US lawmakers. The 1980 Act was a federal policy change that was designed to aid economic development and to increase US commercial competitiveness by allowing non-profits (including universities) to patent federally funded research outcomes. This Act gave universities greater freedom than before to patent discoveries and then sell these technologies to industry for profit. While most academics and proponents of basic science were wary of commercialization, Federal policy-makers saw the commercial potential of academic science in a very positive light. The 1970's were a time when American businesses were losing their international competitive edge. They felt that the passage of this Act would boost industrial know-how to help them compete, improving innovation in high-technology fields such as engineering and life sciences (Mowery, Nelson, Sampat & Ziedonis 2001).

Even after the Bayh-Dole Act was passed, however, providing university policy-makers greater financial incentive to adopt technology-transfer offices, scientists continued to believe that high-quality science and generating money were not complementary practices (Thursby and Thursby 2002). This was true, even as commercialization became more widespread (Owen-Smith 2000). As late as 1994, a professor of pathology at NYU Medical Center argued in a Scientific American essay (Zolla-Pazner 1994) that:

> The demands of (technology transfer on university scientists) drain time and energy. Some research activities are redirected from basic science toward more immediately practical goals. The promise of continuing industrial support is seductive but inevitably tied to commercial products and the bottom line. The lab may find itself focused on an agenda set by the company. The basic research that sparked the initial effort may lie fallow. The spontaneity of scientific pursuit, so prized by those lucky enough to have investigator initiated government research grants, may be restricted. The speed with which the professor can share data or new reagents may be slowed. The result, in the worst scenario, would be deleterious for the lab, harmful for science, bad for society. (p. 120)

Opportunities for universities to diversify their funding base through patented technology became self-evident as the Bayh-Dole Act improved revenue-making potential and a greater number of research universities embraced the marketing and licensing of applied science (Powell and Owen-Smith 1998). Nevertheless, university policy-makers wishing to establish commercialization programs -- particularly during the early years before the Bayh-Dole Act -- faced strong cultural barriers to change.

***Norm Avoidance***

While economic conditions favored the adoption of technology transfer units, in this highly institutionalized context, the loss of legitimacy is a cost that actors typically want to avoid (DiMaggio 1988). It seems reasonable to believe that most universities treaded cautiously when it came to involvement in any practical science -- particularly science transferred to industry for profit. On one hand, additional income generation through patenting was a lucrative opportunity for research universities; housing scientific disciplines with practical applications, they had the resources to roll supplemental income back into the research coffers through contract-based technology transfer. But while they were pressured by the public to embrace their role as sources of basic science for the public good, there was a fear of violating norms.

Universities that had achieved legitimacy through basic research were expected to have embraced the norms of the field. All research universities -- -- those US institutions with a primary mission to conduct research and train graduate students to do so (Carnegie Commission on Higher Education 2000) -- were expected to resist commercialized science. These universities were likely to have attracted attention and, therefore, were more likely to have been concerned about public opinion. As Ahmadjian and Robinson (2001) showed, high-visibility actors were more sensitive to institutional constraints than lower-level actors. This relationship between status and conformity has been well-documented (Blau 1960, 1963; Dittes and Kelley 1956; Harvey and Consalvi 1960; Homans 1961; Menzel 1960).

Some authors suggest, however, that within this echelon, the *highest*-status actors are typically the *least* concerned with their status (Dittes and Kelley 1956;

Hollander 1958, 1960). In a highly institutionalized context, where cultural norms and expectations are relatively stable, the strongest exemplars therein should feel most confident in the durability of their position. Certainly, they should feel more confident in their social acceptance than their less-prestigious counterparts, thus feeling "emboldened to deviate from conventional behavior" (Phillips and Zuckerman 2001). If the prestige of an actor is beyond doubt, there little reason for him to avoid deviating from norms, particularly when he believes that deviance is an effective means to pursue rational ends. In fact, authors have observed this behavior in many contexts where entry barriers privileged the established early-mover (Saloner, Shepard, and Podolny 2001).

If we assume then that the cost of organizational deviance depends upon a university's actions as well as on its current prestige level, than we should assume that the high-status universities felt they had less to lose than others by adopting a technology transfer office. These higher-prestige institutions within the population of research universities should have felt a relatively higher sense of indifference toward normative barriers to commercialized science.

*H1: The higher the prestige of a university, the more likely it was to adopt a technology transfer office.*

Given the strong service-based orientation in higher education, the more normatively-sensitive, lower-status universities should have been expected to reach out to industry only in special cases. Such cases included universities that held a public identity that led stakeholders to associate practical research with serving the public good. Here, the line between what was normatively proper and what was illegitimate -- service to the public and self-interested profit-maximation -- tended to blur. One such identity was that of the land-grant university.

Land-grant institutions were created through the 1862 and 1890 Morrill Acts to meet community technology needs in agriculture and industry (Jones, Oberst, and Lewis 1990). Service to business in the community was in the form of providing "trained graduates, independent studies, expert advisors, and contract research" (Feller 1997: 139). There are now over 70 land-grant universities in the US, playing central roles in economic development -- helping less-developed economies advance toward competitive parity -- at the state and national levels (National Association of State Universities and Land Grant Colleges [NASULGC] 1987). To this day, land-grant universities embrace their public role, and administrators and faculty members at these institutions certainly speak of technology transfer activity and this public service in the same breath. As a recent panel at New York State's land-grant university concludes, "…technology development and technology transfer are important prerequisites if Cornell is to continue to fulfill its land-grant mission of improving livelihoods for the citizens of our community, our state, the nation, and the world" (Cornell University 2002).

Despite this conviction, it is difficult for outside observers to explain all activities undertaken by land-grant universities today by a fiduciary rather than a commercial model. Indeed, it is hard to disentangle revenue generation and economic development as motivations for land-grants engaging in campus-corporate partnerships. As an SRI International Public Policy Center report points out:

> Higher education can meet (economic needs) in ways that enhance their traditional missions. Developing new roles that contribute to economic development can enable these institutions to develop new alliances with industry and government, while expanding their resource base (1986).

Early in the process of commercialized science diffusion, this sort of ambiguity was critical for on-campus advocates of commercialized technology transfer. The fact of the matter is that many early technology transfer office adopters did feel the need to offer justification for contract-based technology transfer (Hughes 2001). Consequently, commercialized science was done with "accompanying publicity that sought to persuade the public that (patenting) was to its benefit" (Hughes 2001: 547). As universities first started to adopt technology transfer offices in the 1970s, most advocates of basic science were wary of programmatic links to the patenting system. Lower-status adopters could avoid controversy by pointing to the position of the patenting office within a larger outreach program, answering a separate service calling.

It stands to reason then that the service-based public identity that land-grant universities have embraced since the 19th Century has kept their industrial use of technology relatively safe from criticism. They have been shielded from institutional stigma through the notion that they have been fulfilling their chartered mission through the growth of industrial ties. This leads to the hypothesis:

*H2: Land-grant universities adopted a technology transfer office at a faster rate than non-land-grants.*

As more commercialization occurred across the population of research universities, the stigma attached to technology transfer office adoption was likely to have decreased. If a single university adopted, it risked attracting attention and criticism. Unless it was a land-grant or a high-status university, this university would have avoided the risk by resisting commercialized science. However, as more universities adopted, potential adopters could have shifted justification from service to the public good (which was reserved for land-grants) to "the time-honored explanation that 'everyone else is doing it'" (Ahmadjian and Robinson 2001). The early stages of the diffusion of technology transfer offices should have involved principally high-status and land-grant research universities. The more universities that went commercial, however, the less likely that remaining universities would have faced the threat of being singled out for doing so. This leads to the hypothesis:

*H3: The more universities that adopted technology transfer offices, the less likely adoption were dominated by land-grant and high-status universities.*

As research shows, rational, efficient motivations for downsizing in a highly institutionalized context awaited the process of legitimation. Where this research shows either a shift from safety-in-numbers to rational factors (Ahmadjian and Robinson 2001) or from social to technical characteristics of individual actors (Leblecici et al 1991), in the field of higher education, multiple factors should have given way to technical consideration as the diffusion process unfolded. High-status universities should have been among the first adopters, as one would assume that they were among the least concerned with the cost of institutional stigma. Land-grant universities should also have been among the first-movers, as their service-based identity should have shielded them from public criticism. Then as the number of adopters increased, the population of all research universities should have felt universally more comfortable commercializing their science. While safety-in-numbers increased the likelihood that any university will adopt, some universities should have felt more compelled to adopt than others. Once the normative pressure to avoid commercialized science subsided, the rate of technology transfer office adoption should have been highest among universities that felt the greatest economic motivation to commercialize their science. As Oliver (1992) points out, as institutional pressure subsides, there is a chance that technical factors might cause organizations to deviate. This leads to the hypothesis:

*H4: As illegitimacy pressures eroded, technical pressures to adopt technology transfer offices were more salient.*

# CHAPTER 3

# DATA AND ANALYSIS

This study reports on a longitudinal analysis of the adoption of technology transfer offices by universities in the United States from 1972 to 2000. While these universities vary in status, resource levels, and institutional characteristics (such as "land-grant"), all 225 are top US research universities. To make the sample, these universities had to have awarded at least ten doctoral degrees per year across three or more disciplines, or at least 20 doctoral degrees per year overall. I rely on classifications by Carnegie Commission on Higher Education, which has been widely used in social scientific research on higher education, to collect this list. There are more than 250 universities that made the list, but only 225 were at risk of adopting a technology transfer offices from 1972 to 2000. While I used adoptions prior to 1972 to calculate prior adopter variables, I dropped them from the at-risk population.

I analyzed the diffusion of technology transfer offices in the US using discrete-time event history models estimated using non-parametric maximum likelihood -- the most suitable models for longitudinal analysis of this kind (Allison 1984; Cox and Oakes 1984). Since records indicated adoption of offices within a bounded period of time, I used a discrete time approach with the unit of time being a full year. Three separate, successive analyses of technology transfer office adoption were used. I began by modeling the 1972-1981 period -- the period before the full implementation of the Bayh-Dole Act. I then modeled the nine-year period following the Bayh-Dole Act implementation: 1982-1990. Universities adopting offices in the previous period were excluded from the analysis. During the earlier period, adoptions were slow and sporadic; during this second period, the population of research universities experienced the first wide-spread growth. Finally, I modeled adoptions from 1991-2000, a period when much pressure to avoid commercialized science had subsided.

***Dependent Variable***

I modeled a single dependent variable to capture the diffusion of commercialized science among universities. Focusing on the university commitment to applied science, I chose to model the adoption of a technology transfer office. The literature on commercialized science in higher education suggests that this event best represents a university's decision to programmatically commercialize their science (Rogers et al 2003). The membership records of the Association of University Technology Managers (AUTM) lists those institutions with at least one full-time employee assigned to technology transfer management, with their hiring dates. I believe that the AUTM accurately represents the population of university technology licensing offices because I could not identify any universities that have technology licensing offices but are not members of AUTM. I lagged this variable one year to allow time for university decision makers to decide on an office then make a full-time employee hiring decision.

***Independent Variables***

*Social Factors.* I used the following measures in my analysis to account for social factors – factors that I expect affected the level of insulation from normative pressure to avoid commercialization:

Status -- I gathered data from the 1983 and 1993 National Research Council (NRC) graduate department rankings to form this variable. The NRC collects its data through a survey of graduate faculty at 3,634 programs around the country, who are asked to rank programs in their field based on the quality of research in these areas (NRC 1995). The NRC rankings have the disadvantage of being gathered only once per decade. However, the 1990's measure is proven to correlate highly with more finelygrained measures of university rankings during this period (Sine et al 2003). Furthermore, the NRC has the advantage of ranking specific departments on a 1 to 5 scale. This specificity allows me to create aggregate scores for all fields and disciplines. For each university, I averaged the scores across disciplines to create the measure. I applied the 1983 measures to all years leading up to 1990 and then used the 1993 measures for the years 1990-2000. This measure is designed to represent the relative status of the university, as determined by its academic peers and professionals in the field of higher education.

Land-Grant – A "1" indicates land-grant members in the National Association of State Universities and Land Grant Colleges (NASULGC).

Number Prior Adopters -- I measured the relative degree of safety-in-numbers among prior adopters through a count of research universities in the population that have incorporated technology transfer offices over the previous 5 years. If the year is 1990, this variable measures total adoptions from 1985-1989. I then weighed this value, based on the geographic distance of each adopter from the focal university. My goal here was to show how, with a rise in the number of recent adopters, pressures against adopting a technology transfer office were minimized. While the cumulative number of adopters is often used in research on innovation adoption, I felt that illegitimate practice adoption is likely affected most by a safety-in-numbers effect, where large numbers of local adoptions make a given any given adopter less visible.

*Economic Factors*. I used the following measures in my analysis to account for economic factors that I expect affected a university's motivation to adopt a technology transfer office, despite the risk of public stigma:

Number Patents -- I measured the number patents awarded to a university for each year in the 1972-2000 frame. All patents assigned to universities during this time were identified through the United States Patent and Trademark Office (USPTO) database.

This measure helped account for each university's raw commercial potential. The patent number was logged to normalize its distribution.

University Budget -- The fastest growing resource for technology innovation on campus is R&D funds. Between 1993 and 2000 alone, R&D budget grew 68% for public institutions and 62% for private. Previous research has shown that organizations seek to reduce their dependence on specific sources of funding. It would seem reasonable then to assume that universities would look to leverage their budgets to create supplemental resource stream though commercial revenues. It might also stand to reason that larger universities with a higher volume of research activity possess the experience and presence to capitalize on commercial research opportunities more effectively than smaller-budget universities. Larger research programs likely adopt offices to leverage this core advantage. I measured the yearly research budget for each university, drawing this data from an online database, the Computer-Aided Science Policy Analysis and Research (CASPAR) database, administered by the National Science Foundation (NSF)'s division of Science Resource Studies. This data set integrates information drawn from yearly surveys of post-secondary institutions and federal funding agencies with National Center for Education Statistics and National Research Council data on higher education institutions. Along with number patents, this measure helped capture the university's raw commercial potential.

State School -- A "1" indicates non-land-grant state universities. University dependence on a high proportion of state funding, which was the case for these universities, should have offered a greater incentive to engage in commercialized science in light of funding scarcity over the last several years.

***Control Measures***

Medical School -- I controlled for the existence of a university-affiliated medical school with a dummy variable of "1" if the university had such a program. Biotechnology and other life science industries increased their dependence on academic research during the frame (Mowery, Nelson, Sampat & Ziedonis 2001). Industry trimmed its internal R&D budgets and turned its attention to medical experts on-campus for some of this technology. The presence of an academic medical center on campus could have led to greater commercial potential than without. Like budget, I gathered these data from the CASPAR database.

High Tech Employees -- I measured the high-end market for university technology through the number of high-technology employees in the county (proximity to high-technology firms should have improved a university's revenue potential). I used the Bureau of Labor Statistics' annual survey of worker demographics to measure high tech employment for each year during the 1972-2000 frame. Following Hecker (1999) I defined high-technology industries as those industries in which research and development employment was at least twice the average for all industries. Values are listed in units of 1000.

Patent Growth -- I assessed the possible technological burden of a university's increased patenting by measuring the percent growth in patenting over the previous three years. A value of "1" for this dummy variable means that the university increased its patents by 25% or more over the past 5 years.

Economic Hardship -- I measured the economic health of the university's local environment each year by calculating the inverse of the average salary-per-employee in the university's county. I used the County Business Patterns archival data –a subset of the US census record – to measure this for each year in from 1972 to 2000. The more depressed, perhaps the more likely the county would have lobbied the university to provide assistance through community outreach.

Density -- To capture potential competitive dynamics, I tallied the number of research universities in an actor's Metropolitan Statistical Area (MSA).

Biotechnology Region -- As mentioned before, growth in patenting was fastest in biotechnology and other life science industries. Location in an active biotechnology region may have conferred commercial advantages to a university. Knowledge spillovers and closer high-tech ties within the geographic cluster may have benefitted the university as it sought to improve its patent portfolio (Jaffe 1986, Romer 1986). Following Owen-Smith and Powell (2003), I constructed a dummy variable for this measure. A "1" means that the university was located in one of the following cities or areas: Boston, SF-Bay, Seattle, San Diego, DC/Bethesda region, or New York City.

***Results***

Tables 1 and 2 report descriptive statistics and correlations for the variables above. After reviewing Table 2., I observed that a few of the variables in my analysis were highly correlated. To bring multicollinearity to an acceptable level, I followed Sine, Haveman, and Tolbert's (2005) suggestion to use a modified Gram-Schmidt procedure (Cohen and Cohen, 1983). This procedure eliminated common variance and created transformed variables for number patents, budget, patent change, and status that were uncorrelated with one another.

Table 3 presents the results from the event history analysis of technology transfer adoption from 1972 to 1981. Model 1 provides a baseline Model that includes all control variables and economic factors. In this model, patent growth is negative and significant, indicating that technology transfer office adoption is not a function of administrative burden. One might suggest that high-patenting universities do not necessarily need offices, and, therefore, avoid the burden of organizing this structure.

Table 1. Descriptive Statistics

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| # patents | 7399 | 0.69 | 1.06 | 0.00 | 5.00 |
| budget | 7399 | 65.22 | 98.20 | 0.00 | 909.49 |
| state school | 7399 | 0.18 | 0.39 | 0.00 | 1.00 |
| med school | 7399 | 0.39 | 0.49 | 0.00 | 1.00 |
| patent growth | 7399 | 0.47 | 0.98 | 0.00 | 5.00 |
| h.t. employees | 7399 | 1.01 | 10.16 | 0.00 | 197.29 |
| density | 7399 | 5.30 | 6.24 | 0.00 | 22.00 |
| econ. hardship | 7399 | 0.07 | 0.05 | 0.02 | 1.19 |
| bioreg | 7399 | 0.17 | 0.37 | 0.00 | 1.00 |
| status | 7399 | 0.78 | 0.97 | 0.00 | 4.03 |
| land-grant | 7399 | 0.26 | 0.44 | 0.00 | 1.00 |
| # prior adoptors | 7399 | 4.36 | 3.59 | 0.00 | 12.84 |

However, results from later stages of commercialization diffusion in the field do not support this, as Tables 4. and 5. show later.

Biotechnology region is also significant, and positive, suggesting that there is some consideration is made for economic factors early in the frame. Model 2 includes the three social variables. The status of adopters significantly increased their rate of adoption, supporting Hypothesis 1. Land-grant universities were also more likely to adopt, supporting Hypothesis 2. As expected, the number of prior adopters had no

Table 2. Correlations

| | Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | # patents | | | | | | | | | | | |
| 2 | budget | .67 | | | | | | | | | | |
| 3 | state school | .06 | .01 | | | | | | | | | |
| 4 | med school | .33 | .46 | .02 | | | | | | | | |
| 5 | patent growth | .75 | .57 | .03 | .30 | | | | | | | |
| 6 | h.t. empl | -.05 | -.05 | -.02 | -.05 | -.03 | | | | | | |
| 7 | density | -.09 | -.11 | -.14 | -.16 | -.03 | .07 | | | | | |
| 8 | econ. hardship | -.12 | -.09 | .03 | .04 | -.10 | -.04 | -.18 | | | | |
| 9 | bioreg | .05 | .17 | -.05 | .05 | .00 | -.04 | .00 | -.19 | | | |
| 10 | status | .57 | .75 | .11 | .43 | .51 | -.05 | .01 | -.10 | .11 | | |
| 11 | land-grant | .15 | .32 | -.28 | .20 | .08 | -.03 | -.14 | .11 | -.10 | .22 | |
| 12 | # prior adopt | .14 | -.09 | .02 | -.05 | .11 | .01 | -.01 | -.10 | -.07 | -.19 | -.04 |

significant effect during this period. Furthermore, from 1972-1981, only biotechnology region remained significant among control measures, and no other factors related to economic opportunity emerged. Hypotheses 3 and 4 were thus supported. Comparing the two nested models, Model 2 had a significant increase in fit over Model 1.

Table 4 reports analysis results from 1982 to 1990. Model 1 shows that economic factors start to emerge as predictors of office adoption. Here, budget and medical school are both positive and significant. The number of patents is still less significant and negative, which is counter-intuitive. However, the positive, significant

Table 3. Event History Analysis:
Technology Transfer Office Adoption, Early Stage (1972-1981)

| | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | Coeff. | S.E. | Sign. | Coeff. | S.E | Sign. |
| # patents (log) | -0.83 | 0.24 | | -0.09 | 0.33 | |
| budget | 0.29 | 0.24 | | 0.29 | 0.28 | |
| state school (1/0) | 0.20 | 0.46 | | 0.96 | 0.57 | |
| med school (1/0) | 0.43 | 0.47 | | 0.32 | 0.47 | |
| patent growth | -0.79 | 0.33 | * | 0.15 | 0.44 | |
| h.t. employees | 0.01 | 0.19 | | 0.01 | 0.17 | |
| density | -0.10 | 0.18 | | 0.07 | 0.19 | |
| econ. hardship | 0.04 | 0.03 | | 0.03 | 0.04 | |
| bioreg (1/0) | 1.13 | 0.44 | ** | 1.20 | 0.45 | ** |
| status | | | | 0.70 | 0.29 | * |
| land-grant (1/0) | | | | 1.13 | 0.53 | * |
| # prior adoptors | | | | -0.18 | 0.28 | |
| | | | | | | |
| subjects | | 256 | | | 256 | |
| failures | | 30 | | | 30 | |
| observations | | 2466 | | | 2466 | |
| LR chi2 | | 33.18 | | | 44.20 | |
| prob > chi2 | | 0.0001 | | | 0.00 | |

* significant at 5%; ** significant at 1%

emergence of two non-social factors suggests that pressure to resist commercialized technology may be subsiding. Social variables are added again in Model 2. Status is

still significant, but its coefficient is reduced. Also, land-grant drops out as a significant variable. Once these social variables are included, budget is the only economic factor that remains significant. Nevertheless, this factor's resilience suggests that, as more universities have adopted, the likelihood that additional

Table 4. Event History Analysis:
Technology Transfer Office Adoption, Middle Stage (1982-1990)

| | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | Coeff. | S.E. | Sign. | Coeff. | S.E | Sign. |
| # patents (log) | -0.50 | 0.21 | * | -0.21 | 0.17 | |
| budget | 0.68 | 0.17 | ** | 0.98 | 0.24 | ** |
| state school (1/0) | -0.01 | 0.34 | | -0.22 | 0.41 | |
| med school (1/0) | 0.84 | 0.30 | ** | 0.34 | 0.32 | |
| patent growth | -0.35 | 0.20 | | -0.13 | 0.15 | |
| h.t. employees | -0.21 | 0..27 | | -0.22 | 0..28 | |
| density | -0.03 | 0.17 | | -0.11 | 0.18 | |
| econ. hardship | 0.00 | 0.02 | | 0.01 | 0.03 | |
| bioreg (1/0) | -0.57 | 0.51 | | -0.61 | 0.52 | |
| status | | | | 0.86 | 0.19 | ** |
| land-grant (1/0) | | | | -0.27 | 0.39 | |
| # prior adoptors | | | | 0.26 | 0.07 | * |
| | | | | | | |
| subjects | | 225 | | | 225 | |
| failures | | 56.00 | | | 56 | |
| observations | | 1614 | | | 1614 | |
| LR chi2 | | 51.90 | | | 76.00 | |
| prob > chi2 | | 0.00 | | | 0.00 | |

* significant at 5%; ** significant at 1%

universities established offices increased -- particularly those universities with commercial potential. These findings support Hypotheses 3 and 4; land-grant and high-status characteristics begin to make way for safety-in-numbers and, to some degree, economic factors. As in Table 3, the second model in Table 4 had a significant increase in fit over the first model.

Table 5 reports results from the analysis covering the final 10 years of the frame: 1991-2000. Model 1 findings suggest that economic factors are strong motivators during this period. Budget (i.e., commercial potential) is still significant

Table 5. Event History Analysis:
Technology Transfer Office Adoption, Late Stage (1991-2000)

| | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | Coeff. | S.E. | Sign. | Coeff. | S.E | Sign. |
| # patents (log) | 0.44 | 0.13 | ** | 0.34 | 0.15 | * |
| budget | 0.65 | 0.18 | ** | 0.85 | 0.23 | ** |
| state school (1/0) | 1.06 | 0.30 | ** | 1.04 | 0.37 | ** |
| med school (1/0) | -0.06 | 0.32 | | -0.28 | 0.33 | |
| patent growth | -0.14 | 0.10 | | -0.22 | 0.11 | |
| h.t. employees | -0.10 | 0.09 | | -0.10 | 0.09 | |
| density | -0.16 | 0.23 | | -0.22 | 0.24 | |
| econ. hardship | 0.03 | 0.03 | | 0.01 | 0.03 | |
| bioreg (1/0) | -0.03 | 0.54 | | -0.24 | 0.56 | |
| status | | | | 0.82 | 0.24 | ** |
| land-grant (1/0) | | | | 0.23 | 0.41 | |
| # prior adoptors | | | | 0.15 | 0.08 | |
| | | | | | | |
| subjects | | 169 | | | 169 | |
| failures | | 55 | | | 55 | |
| observations | | 1403 | | | 1403 | |
| LR chi2 | | 55.77 | | | 70.10 | |
| prob > chi2 | | 0 | | | 0 | |

* significant at 5%; ** significant at 1%

and positive. The number of patents (also commercial potential) is significant as well; only in this analysis, number of patents is positive. While medical school is no longer significant, state school (required funding) is significant and positive.

To test the strength of this idea, Model 2 includes the social variables. Model fit is improved, and only prestige is a significant predictor of technology transfer adoption. The three economic factors in Model 1 are still significant in Model 2, which provides strong support for Hypothesis 4, as expected. Comparing results across time periods, one can see that economic factors are not only highly predictive, but these factors also have greater predictive power during 1991-2000 than during

1982-1990. These results, coupled with the reduced impact of both number prior adopters and land-grant mission, suggest that social factors started to make way for economic factors -- commercial potential and funding requirements -- through the three decades observed.

# CHAPTER 4

# CONCLUSIONS

Most studies of technology transfer activity have emphasized the economic and social factors that have affected the relative success of universities commercializing their science over the last 10-15 years and the cultural problems associated with this on-campus activity. While this research has provided good insight to help us better understand the context within which commercialization spread, little research has examined how cultural shifts in the views of the commercialization of university research affected the importance of economic factors in determining the adoption of technology transfer offices throughout the population -- how cultural barriers and normative protection mechanisms interact to shape the speed and direction of technology transfer office adoption among major research universities in the US. An investigation of diffusion trends across three decades of commercialized science shows that individual and population-level factors affected the impact of normative pressure to resist university technology transfer activity. Furthermore, it shows that these factors shifted over time.

The meaning of these social factors can be traced to the relative pressure that universities faced as they adopted an illegitimate practice. Social cost avoidance was a much greater concern than relative economic benefit early on. In fact, neither budget nor patent levels were strong predictors of technology transfer office adoption during the 1970s. During this time, when adoption was sparse, the first-moving high-status and land-grant universities felt the least amount of pressure to avoid moving into commercialized science. High-status universities that were indifferent toward social pressure and land-grants that had a service-based identity that shielded them from criticism were positioned to worry the least about stigma.

Then, as years went by and more universities established technology transfer offices to bring technology to market, diffusion was no longer channeled through just the land-grant and high-status universities. While indifference and identity were the most effective layers of insulation from criticism through the 1970s, these individual characteristics gave way to population-level factors in the 1980's. Results show that normative protection became more a function of the number of prior adopters than land-grant identity, and while status was still important during this time, its impact was reduced.

As the analysis then suggests, economic pressures to adopt became more salient as the legitimacy of engaging in commercialized science increased. During the final ten years of the frame, universities that could realize the greatest economic benefit from the technology transfer office – universities with high commercial potential or funding needs – were comfortable enough to adopt without the need for normative protection. Land-grant identity and safety-in-numbers were insignificant predictors of technology transfer adoption throughout the 1990's.

In summary, key decision makers within an organization must deal with cultural inconsistencies that exist between an efficient practice and its environment. To minimize the cost of social criticism, cultural resources must be available to these decision-makers if they are to fully realize the economic benefit that a practice might hold in store for them. Results here show that in the field of higher education, specifically, a university's status or identity as a land grant university, then its position among early adopters, insulated decision-makers in the field of higher education from this social stigma. Universities with a mission that required dealing with practical science, a level of status that was relatively immune from institutional criticism, and a comfortable number of prior adopters around them that they could point to for protection were the quickest to adopt an illegitimate practice – the commercialization their own technology for profit through a technology transfer office.

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