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Technology Commercialization Effects on the Conduct of Research in Higher Education

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Abstract

The objective of this study was to investigate the effects of technology commercialization on researcher practice and productivity at U.S. universities. Using data drawn from licensing contract documents and databases of university-industry linkages and faculty research output, the study findings suggest that the common practice of licensing technologies exclusively to singular firms may have a dampening effect on faculty inventor propensity to conduct published research and to collaborate with others on research. Furthermore, faculty who are more actively engaged in patenting may be less likely to collaborate with outsiders on research while faculty at public universities may experience particularly strong norms to engage in commercialization vis-à-vis traditional routes to research dissemination. These circumstances appear to be hindering innovation via the traditional mechanisms (research publication and collaboration), questioning the success of policymaking to date for the purpose of speeding the movement of research from the lab bench to society.

Keywords

technology transfer in higher education; commercialization; patenting

In recent years, much attention has been given to the translation of academic science into products and processes of practical societal benefit (Etzkowitz, Webster, & Healey, 1998; Powers, 2003, 2004b). One increasingly common mechanism has been through technology transfer, the process by which a university sourced technology is developed, transferred to industry, and ultimately produced into a consumable product. Beginning in 1980, the federal government began enacting a series of policies designed to incentivize a stronger triple-helix like relationship between the federal government, universities, and industry with the intent of speeding the movement of technologies to the marketplace. In a few short decades, new or expanded technology transfer infrastructures have been built on university campuses, all designed to better leverage the intellectual capital of its researchers and facilitate the transfer of technologies to the private sector.

As an outgrowth of market forces entering more centrally into the conduct of science, the means of research dissemination has also changed. Whereas in the past the transfer of research to industry and/or other researchers was done almost exclusively via publication, professional conference presentations, or other free and open exchanges between persons and organizations, today it increasingly occurs via contract such as through a material

transfer agreement or a technology license. What is occurring is a reorientation of research as an intellectual property rather than an intellectual commons (Argyres & Liebskind, 1998) and something that is considered to have monetary value that needs to be protected. These market-like forces are what Slaughter and Leslie (1997) call academic capitalism. With the advent of Recombinant DNA and the revolutionary potential of biotechnology for human health, as well as strong forces emphasizing higher education's contribution to economic development, researchers and their sponsoring institutions are actively seeking patent protections for their work and seeking to license it to industry, hopefully as a source of significant revenue returns.

Among the emergent issues associated with academic capitalism is the degree to which the new contractual exchange relationship may be impacting follow-on innovation (Cho, Illangasekare, Weaver, Leonard, & Merz, 2003; Rai & Eisenberg, 2003). Some have argued that the rise in academic-industry partnerships in the life sciences and the high visibility of key success stories are evidence that follow-on innovation from basic technologies are being translated into bone fide products of practical utility to consumers (Etzkowitz, 1998; Tornquist & Hoenack, 1996). Others have voiced concern that the exclusive licensing of basic technologies to single firms and the restrictions that creates for other researchers to develop a technology for alternative, possibly even unknown applications, actually hinders the pace of innovation (Eisenberg, 2000; Heller & Eisenberg, 1998).

Most research to date has been of a case study nature or driven by survey research of faculty or technology transfer professionals. While helpful, this methodological approach is nonetheless subject to memory recall challenges and in the important controversial arenas, potentially subject to bias. To date, no research has investigated what is actually occurring as evidenced through contractual documents rather than what faculty or commercialization staff say is occurring. The objective of this study was to help fill this knowledge gap by exploring licensing practice at research universities and its impact on inventor-researcher publishing productivity and scholarly collaboration patterns.

The following three questions guided this research study:

1. What affect does exclusive licensing have on inventor follow-on research productivity and collaboration?
2. Does the breadth of the potential application of a technology have an affect on inventor follow-on research productivity and collaboration?
3. Are there differences in follow-on research productivity and collaboration patterns based upon university type (public or private)?

Theoretical Frameworks

Innovation Diffusion

A considerable body of research has focused on the mechanisms and processes associated with the diffusion of innovations (e.g., O'Neill, Pouder, & Buchholtz, 1998; Rogers, 1983). Rogers defined an innovation "as an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (p. 11). Diffusion is the process by which an innovation is communicated through channels over time among the members of a social system. In the case of innovations associated with the research enterprise, Rogers argued that it begins with basic research and the investigation of fundamental processes without the specific objective of solving an identified problem. Basic research in turn stimulates follow-on applied research which focuses on the use of specific basic technologies to aid in solving practical problems. Once the fruits of applied discovery are made, development occurs as technologies are "developed" into forms with application to specific adopters. Finally, the

process ends with commercialization, the point at which a technology is embodied in the form of a specific product or process made available for consumer purchase and distribution.

Research on knowledge flows (Feller, 1990; Rosenberg & Nelson, 1994) and the technology transfer enterprise (Siegel, Waldman, Atwater, & Link, 2004) has affirmed this progressive path. Yet, as universities have matured in their approach to technology transfer, what appears to be occurring is a more iterative and cyclical process of innovation diffusion. The double-helix character of DNA has been metaphorically adapted to describe the university-industry-government relationship, this time as a triple-helix. The intertwined relationship suggests that the movement of knowledge is not necessarily one way but rather cycles in and out of each triple-helix partner depending on the nature of the technology and the sources of intellectual capital best suited to its movement through the four phases suggested by Rogers (1983). Cohen, Nelson, and Walsh (2002), for example, in their study of industry R&D, found that contrary to popular belief, university-sourced research generates both new R&D projects but also contributes to the completion of existing projects that may have transferred to industry at an earlier point or that were even sourced in industry in the first place. They also found that knowledge flows were much more diverse than they had been in the past with publications and paper presentations at meetings being just two among a wide array of transfer mechanisms. New forms of transfer were becoming increasingly common such as through consulting, joint research ventures, patenting, licensing, and contract research.

Within the burgeoning literature of innovation diffusion has been an expanding focus of research on the new forms of entrepreneurial activity in which public research organizations are becoming involved. Research investigating knowledge flows through patenting mechanisms, for instance, has received considerable attention in recent years. Narin, Hamilton, and Olivastro's (1997) research has documented the increasing frequency with which research papers are being cited in U.S. patents. Shane (2001) found a similar effect as it regarded quality measures of academic patents and the extent to which high opportunity patents stimulated the creation of new firms. Murray (2004) found that faculty are becoming more centrally important to the success of biotechnology companies via membership on scientific advisory boards, co-authors with industry scientists, and even in the controversial role of firm management. As it regards licensing from universities, recent research has documented how institutional prestige stimulates innovation diffusion to industry via licensing (Sine, Shane, & DiGregorio, 2003) and that exclusive licensing appears to be associated with more licensing deals with private companies that ultimately go public (Powers, 2004a). Related research has found that the involvement of faculty in helping to identify licensing opportunities, assisting with follow-on development after a licensing deal is consummated, and participating in company sponsored research projects is also common and important (Thursby & Thursby, 2004).

The new helix-like relationships have led to rising concerns that certain mechanisms may be better than others and that patenting and exclusive licensing of technologies may actual thwart rather than enhance innovation (Angell & Relman, 2002; Barton, 2002). The exclusive licensing of basic technologies are especially worrisome since one can only guess at the possible applications. Furthermore, access to critically important research tools (Barton) has been raised as a significant issue since these platform technologies are essential to the conduct of science.

The research literature described above suggests that technology transfer in general and licensing in particular does have downstream impact and that exclusive licensing is widely employed (Henry, Cho, Weaver, & Merz, 2002). Case study and related research suggests that exclusivity may have a dampening effect on the ability of persons not party to a license to utilize the technology for follow-on innovation. Exclusive licensing may discourage or

prevent inventors from engaging as robustly in ongoing research and outsider collaboration due to licensing contract restrictions on what the inventor can write and publish. The personal profit incentive is also strong since a researcher who makes it difficult for others to have access increases the chances that others will not build upon it or be able to circumvent their technology.

Although the research just described would suggest a potential negative effect of exclusive licensing on innovation diffusion, it is also likely that the innovative potential of the technology itself will have an effect as well. A number of researchers who study innovation diffusion emerging from technology transfer have investigated various aspects of a technology in terms of its impact or potential impact on future innovation. One common method for doing so is via particular pieces of information found in a patent listing that may signal others about its potential downstream importance. Previous research, for example, has shown that the breadth or scope of a patent, defined as how many international patent classes it covers, is predictive of the quantity of venture financing that the firm is able to attract to develop the technology (Lerner, 1994). Others have found that the number of citations to the science literature listed by a patent is a positive predictor of the downstream value of a technology (Harhoff, Scherer, & Vopel, 2003).

Thus, the breadth or importance of a technology in terms of possible applications may play a role in how much effort others are willing to expend to seek access to a licensed technology for follow-on research purposes. In addition, technologies with broad potential applications may necessitate the inventor to collaborate with others because those applications transcend their particular skills sets.

Agency Theory

Agency theory focuses on organizational relationships where a person or entity called a principal chooses/needs to delegate responsibilities to another person/entity who then carries it out on their behalf (Eisenhardt, 1985). Central to the theory is that incentive systems are needed to ensure that agent-principal goals remain aligned. Thus, contracts and decision making principles are drawn up to clarify expectations of agents and compensation structures created to align principal-agent self-interests. Furthermore, principals create monitoring mechanisms such as financial reporting requirements, empower principal staffed oversight boards, and require organizational information disclosure. These monitoring efforts are designed so that principals can appropriately assess organizational health and performance and initiate changes if needed.

Unfortunately, in an environment of imperfect communication and uncertainty, principal-agent problems can ensue in which agents take greater risks or financially enrich themselves to a higher degree than principals would find acceptable (Eisenhardt, 1985). However, ambiguity over organizational activities and outcomes makes it hard for principals to recognize it. Possible principal-agent problems exist for academic science technologies and their development (Agyres & Liebeskind, 1998; Angell, 2000; Henry et al., 2002). It is difficult for the American public as principals to ascertain whether or not the choices that university makes is in fact in their best interest, the perfect environment for agents to pursue more self-interested and risk tolerant commercialization goals.

In American higher education, however, the tightness of coupling between the public and a university differs based upon institutional control. Public institutions are much more accountable to the state, for example, as a function of it receiving appropriations that private institutions do not. State legislators such as the governor, acting as proxy principal, typically populates the university's Board in part or in total as one way to maintain control or close watch on the affairs of the agent institution while in the private university, board

membership is typically fully within the institution's control to populate. State regulatory controls are also often different between the two types of universities, providing more freedoms for the private institution for the conduct of its affairs.

In light of possible less tightly coupled principal-agent linkages for private universities than for public ones, private universities may not be as attentive to ensuring wide access to their technologies as would public universities, regardless how the technologies are licensed. Public institutions likely also feel more pressure to ensure that their innovations are accessible for in-state economic development while privates may feel greater freedom to pursue technology licenses wherever they see fit. As a result, private university inventors with licensed patents may feel less pressure to collaborate with others in their research given comparatively fewer restrictions on their ability to personally profit from their work. In sum, principal-agent forces may have differentially impacted the norms of commercialization practice for public versus private universities.

Considering the dual theories of innovation diffusion and agency theory, the following theoretical model is proposed for testing in this research:

In summary, drawing from innovation diffusion theory literature, we hypothesize that exclusive licensing will have a chilling effect on innovation diffusion, the propensity of a faculty inventor to collaborate with others in their research activities. Non-exclusive licenses provide broader access to a technology for commercial development and reflect norms more closely aligned with the traditional ones in higher education for the conduct of research. Hence, this would infer a negative relationship between exclusive licensing and innovation diffusion. As it regards technology innovative potential, we hypothesize a positive relationship. Technologies with broader potential applications will likely stimulate greater research collaborations either because the technologies are seen as more valuable to the advancement of science (and others then wish to be involved) or the nature of that breadth simply requires others with different skills sets. In light of the agency theory literature and what may be stronger principal-agent relationships at public universities on the conduct of science than at private institutions, we hypothesize that the source of a technology (i.e., from a public versus private university) will also be positively related to innovation diffusion.

Methodology

Sample

The sample for this study consists of 215 licensing deals involving 345 patents between firms in the life sciences industry and 60 U.S. universities between 1990 and 2002. The life sciences industry was chosen for three reasons. First, these kinds of technologies are at the epicenter of the technology transfer debate given their potential for significant breakthroughs in human health and hence the need to ensure that they are disseminated in an optimal manner. Second, they have typically been the most lucrative kinds of licensed technologies and the most common examples of blockbuster success, a major enticement to universities in difficult economic times. Finally, life sciences research support is by far the largest source of R&D funding for universities and thus research that focuses here in particular can guide this enormous enterprise in higher education.

The licensee firms in the data set were predominantly U.S. based but also firms headquartered in areas around the globe, particularly Canada, Europe, and Asia. Sixty-percent of the firms were public companies at the time of the licensing deal while 40% were private. The 30 public and 28 private universities in the sample were all top 100 research universities. Thirty-two of the deals were made non-exclusively while 313 were made exclusively.

The data for the study were collected from a variety of sources following a sequence pattern to collect the information of interest. First, licensing deal information for the years 1990–2002 were mined from the Recombinant Capital database, a firm that tracks alliances in the life sciences industry. From the information listed about the deals, press releases that may have been issued, and secondary searches of the Securities and Exchange Commission (SEC) database or over the Internet, information about the technology, the date of the deal, the inventors involved, and patent numbers that could then be matched up with patent information available in the U.S. Patent Office database were obtained. From this point, primary inventor name searches were conducted through the Web of Science database to mine salient authorship and collaboration information five years before and five years after the license date.

Variables

Dependent Variables

Four continuous measures of innovation diffusion were identified and operationalized as dependent variables for this study. These variables were as follows:

Number of inventor publications—Considering that a primary mechanism by which innovation is diffused from universities is through publication (e.g., journal articles, conference proceedings, etc.), we utilized a count of article publications of the faculty inventor within five-years following the date of the license. This measure of follow-on research was designed to capture a traditional way in which faculty scholarly productivity is measured and innovation gets diffused. The data was collected from Web of Science.

Number of publications with outside collaborators—While aggregate publication counts are one way to measure innovation diffusion, another way identified for this study was counts of articles in which the inventor had an outside co-author. Thus, we summed the number of articles published within five years after the license date in which at least one co-author on the article with the inventor was not affiliated with the inventor's institution or the firm that had licensed the technology. Given that open science and the sharing of research findings and data with others is considered a core facilitator of innovation diffusion from universities, we developed this variable as a way to measure possible affects of licensing practice and the nature of academic-sourced innovations on follow-on research collaboration involving persons not party to the licensing contract. This data was collected from Web of Science.

Number of outside collaborators on publications—A third way we operationalized innovation diffusion was via counts of outside collaborators (i.e., persons not affiliated with either the technology licensee or licensor) on publications also authored by the source inventor. Some have argued that the forces of privatization may stimulate researchers and their institutions to guard innovations closely and to be reluctant to share with outsiders either out of licensing contract restriction or a fear of erosion in potential downstream financial payoffs. To develop the measure, we summed the number of outside co-authors across all of the publications involving the inventor five years after the date of the license. The data was collected from Web of Science.

Number of inventor publications with outside collaborators per total number of publications—A fourth measure of innovation diffusion we investigated was a relative one, in this case a variable that captured the proportion of article publications of an inventor in which there was at least one outside co-author collaborator to the total number of the inventors publications within five years of a license date. This measure provided a

perspective on the pattern of research productivity involving single authored work and work involving just insiders vis-à-vis one's total research productivity. This measure was developed from data mined from Web of Science.

Independent Variables

Licensing exclusivity—As noted earlier, licensing practice effects on innovation diffusion was a primary interest of this research. Specifically, we wished to investigate if there is a significant association between exclusive licensing (versus non-exclusive licensing, both forms of which are practiced) and follow-on research or follow-on innovation. This data point was mined from Recombinant Capital's database, the SEC database, or other secondary sources such as press releases that could be located and that clearly described the nature of the license deal in this manner. Exclusive licenses were coded with a 1 while non-exclusive licenses were coded with a 0.

Number of patent classes in a licensed patent—Following the approach used in previous research (Lerner, 1994; Shane, 2001), the breadth or scope of a technology was investigated for this study. Specifically, we created a count of the number of international patent classes that the U.S. Patent Office assigned to a given patent. Patent classes are the way that the U.S. Patent Office demarks the technological coverage of a patent. More patent class coverage would infer greater potential applications.

Number of reference citations in a licensed patent—Also building upon the work of others (Harhoff et al., 2003), this study utilized a second measure of patent breadth, the number of reference citations to other research found on a given patent. Patented technologies with a greater number of literature references would potentially infer greater breadth or importance of the technology.

Public versus private university—As discussed earlier, possible differences in attitudes and approaches to commercialization may exist between public and private universities and thus would be important to test as it regards its affect on innovation diffusion. A dummy variable was created in which a public university was coded a 1 and a private university a 0.

Control Variables

Inventor previous publications with collaborators—Since the number of publication collaborations with outside researchers prior to a licensing deal would likely be associated with their post-deal collaboration practices, it was also included in this study. Data for this measure was collected in a similar manner as the previous control variable. A relative measure of collaboration was also created and used in the investigation involving the fourth and mirror dependent variable noted above.

Inventor previous collaborators—A third control for previous publication related activities that was included focused on the number of previous collaborators that an inventor had during the five years prior to their license deal. Data was collected from Web of Science.

Inventor previous patents—Patenting activity prior to a licensing deal would likely be associated with an inventor's orientation to research and commercialization after a deal and thus was also included in the models to control for this possible effect. Data came from the U.S. Patent Office database and also measured five years prior to the licensing deal.

Time—Given the time frame involved (1990–2007), it was important to include a variable that controlled for time. Thus, a time variable was included and operationalized as the

number of years from 2007 that the licensing deal was executed. However, licensing deals were only considered through 2002 in order to ensure the requisite five years post-licensing deal analysis was possible.

Results

The descriptive findings are reported in Table 1. As can be seen, the data revealed an average publication productivity post license of 29.77 versus 24.55 prior to the license date, an average number of articles with collaborators after the license of 14.53 with 10.87 prior to the license, and an average number of post-license outside collaborators of 54.25 versus 35.95 prior to the license. Furthermore, the respective relative measures of innovation diffusion revealed that approximately 45% of articles published in the five years after the license date involved outside collaborators while 41% of articles involved outside collaborators prior to the license. This aggregate increase in productivity would be expected of researchers who mature in the field, confront increased pressure to engage in publication, and who are already highly productive researchers.

Table 2 presents the correlation matrix as a means of initial testing for possible collinearity. The data revealed one control variable correlation at .61, the one involving the ratio measure of collaboration and the number of previous publication collaborations. Since the one ratio measure of collaboration would be substituted for the number of previous publication collaborations in the investigation involving its mirror follow-on counterpart and all of the other variable correlations were no higher than .28, it did not suggest the presence of collinearity. Additional variation inflation factor diagnostics and condition indices well within acceptable ranges further affirmed that the data were acceptable for regression analysis.

Regression Analyses

Table 3 presents the results of the hierarchical regression analyses with the control variables entered in the first step and the independent variables entered in the second step. Because of skewness in the data, the dependent variables in models 1–3 were log transformed as were the two measures of patent breadth, the previous publications with collaborators control variables, and the previous patents control variable. Coefficients are standardized betas.

Model 1 examined the affects of the variable sets on inventor publication productivity five years subsequent to the license deal. Both the partial and full models were significant ($p < .001$) with the full model explaining 46% of the variance. In model 2, publications with outside collaborators for the five years after the license, both partial and full models were again significant ($p < .001$) with the full model explaining 51% of the variance. Model 3 investigated the number of publication collaborators during the five years subsequent to the deal. The partial and full models were also both significant ($p < .001$) with the full model explaining 49% of the variance. For model 4, the partial and full models were again both significant ($p < .001$) with the full model explaining 19% of the variance.

Licensing exclusivity was negatively associated with the dependent variable in all four models. Given exclusive licensing was coded with a 1 and non-exclusive licensing a 0, this infers that non-exclusive licensing is associated with greater follow-on publications and all three measures of research collaboration. The second independent variable, technology scope, a measure of patent breadth, was not significant in any of the models. This suggests that the measure does not appear to be associated with the overall number of inventor publications nor any of the measures of collaboration. The other measure of patent breadth or importance, the number of reference citations in the patent, was positively significant in model 3. This infers that licensed patents with more cited references are more likely to be

associated with the number of outside collaborators but not with the overall number of publications, publications with outside collaborators, or the relative measure of collaborative publications per total number of publications. The final independent variable, public versus private university, was negatively associated with the number of inventor publications (model 1). Since public universities were coded with a 1 and private universities with a 0, this suggests that private universities in the sample evidenced more inventor publications.

Among the control variables, inventor previous publication collaborations was positively significant across all four models ($p < .001$). Inventor previous patents was negatively significant in model 3, inferring that inventors with more patents are more likely to evidence fewer outside collaborators. Time was negatively significant in models 2–4, suggesting that inventors involved more recently in licensing are more likely to have a greater quantity of all forms of collaboration than inventors engaged in licensing activity during earlier periods.

Discussion

The purpose of this study was to investigate the affect of technology commercialization on innovation diffusion measured in two ways, one via follow-on publication counts of inventors post-license deal and the second via three measures of follow-on collaboration, namely, the number of articles published with outside collaborators, the number of outside collaborators, and the number of collaborative publications per total inventor publications. The results indicated that among licensing deals emerging from U.S. universities, the way in which a patented technology is licensed (exclusive versus non-exclusive) does appear to have an effect on both productivity (aggregate publication output) and on the extent of collaboration with persons not a party to the license (outside the university and the licensee firm).

This finding is a noteworthy one as it is the first to show with a large dataset focused on this topic that exclusive licensing may have a dampening affect on innovation diffusion. It also supports what some others have found in this regard in smaller scale surveys and/or focused studies in the arena of genetics research in universities (Cho et al., 2003; Schissel, Merz, & Cho, 1999). It also aligns with the work of Murray and Stern (2007) who found evidence of an anti-commons effect defined as falling citation rates of scientific publications after a patent issue.

In addition to the exclusivity finding, it was also informative that a patented technology's breadth as defined by the number of patent classes was not associated with publications or outsider collaboration. Hence, the patenting breadth signal affect that others such as Shane (2001) and Lerner (1994) have found with the number of patent classes variable does not appear to hold, at least not in this study. In terms of the other measure of patent breadth or importance, reference citations in a patent, it was positively associated with the number of outside collaborators. This operationalization of the potential application opportunities of a technology, then, may be a stronger signaling mechanism to other researchers, possibly also to the likelihood that an inventor or inventor team will need or desire outsiders to assist in the technology's further development. Furthermore, a larger number of citations may also reflect an inventor's greater engagement with research and familiarity with the field, key characteristics that may put him or her in closer contact with potential outside collaborators.

As it regards possible principal-agent linkage differences between public and private universities, the findings suggest that there may be differences in publication output among the faculty inventors at the respective institution types. The result infers that faculty engaged in patenting and licensing at private universities may have greater institutional expectations to disseminate knowledge in multiple ways (i.e., the proprietary route as well as the free

route through academic publishing) than faculty at public universities. Given the growing emphasis state legislators are placing on public universities for contributing to the state's economic future, it may be that this pressure is coming at the expense of traditional routes to knowledge dissemination. In summary, the extent of a public institution's patent portfolio may be seen as growing in importance vis-à-vis publication productivity. Nevertheless, there do not appear to be significant differences in outsider collaboration on the research that is produced in either institutional setting.

Among the control variables, the mirror collaboration variables were significant as expected. Previous patents in model 3 was significantly associated with the number of outside collaborators in the negative direction, inferring the possibility that inventors with more patents may be less inclined to collaborate. Time was negatively significant across all three collaboration measures, inferring that inventor-researchers with more recent license deals are more likely to have a greater propensity to collaborate and to collaborate as a proportion of their total portfolio of research activity, perhaps as a function of recent efforts by the National Institutes of Health and others to emphasize collaborative, large science projects rather than individual ones.

Implications for Policy and Practice

The anti-commons concerns raised by some as a byproduct of academic technology transfer were substantiated in this study. Exclusive licensing at research universities does appear to have a dampening effect on what at least historically has been viewed as an engine of innovation diffusion, the free exchange of ideas and the building upon of others work. Furthermore, patenting activity in general appears to have a dampening effect on research collaboration. Finally, principal-agent relationship differences, possibly fueled by excessive expectations placed on public colleges and universities as drivers of economic development may also be dampening the historic forms of knowledge dissemination.

In light of the study findings, three recommendations for university practice are offered. First, much of what emerges from the research enterprise in higher education, particularly in the life sciences, is as fundamental platform technology needed to advance a field of study. Given that the common practice of exclusive licensing appears to have a dampening effect on an inventor's publication output and collaboration patterns, universities would be wise to rethink the benefits and costs to such practices. Whereas exclusive licensing may increase the chances that a firm will agree to a license, there is no guarantee that the license will lead to a new consumer product or process but does appear to have the potential to reduce the likelihood that the inventor researcher will be as productive or willing to share knowledge with other researchers through traditional routes. Hence, using exclusive licensing more selectively and when used, utilizing clear fields of use defined as narrowly as possible is needed. Furthermore, it is also important to ensure that contract language provides unfettered access to the technology by inventors and their collaborators for research purposes.

Second, universities would be wise to consider adopting guiding principles of practice that facilitate rather than hinder follow-on research and collaboration. For example, Stanford University, a consortium of other universities, and the Association of American Medical Colleges (2007) urged the adoption of nine-key points for commercialization practice, including ensuring broad access to research tool technology, exclusive licenses that are narrow in focus, and that weight conflict of interest considerations in policy development. The National Institutes of Health and other leading biomedical organizations and associations have also put out similar types of guidelines that would be wise for adoption.

Missing in most of these guidelines and policy documents, however, is clarity over what should be done when an institution or a researcher violates a norm or policy.

Finally, this research suggests that state and federal policymakers would be wise to consider reviews of existing laws and regulations that may inadvertently contribute to a culture of secrecy and self-interestedness in research activity. With the resources and energy being invested in efforts to stimulate economic development, institutions may feel pressed to orient support toward those strategic fields that are closer to the marketplace, irrespective if the institution is appropriately suited for such a pursuit or if those activities are in the public interest. For example, there has been an enormous growth in construction of life science infrastructures at universities all over the country. However, some institutions have had considerable difficulty maintaining these programs, suggesting that the investments might have been better optimized if done more strategically.

Limitations and Opportunities for Future Research

This study provided new evidence of ways in which a commercial orientation within universities may hinder rather than stimulate innovation diffusion, suggesting a rethinking of the means of new knowledge production (Hessels & van Lente, 2008). Yet, the study is not without its limitations. First, innovation diffusion occurs in many ways other than how it was measured in this study. For example, follow-on patenting was not investigated, a clear means by which innovation is disseminated and developed. Innovation diffusion also occurs through presentations at conferences, a source of diffusion not measured in this study unless a paper presented at a conference appeared in the Web of Science database. Faculty are also involved in consulting with industry, a third way that ideas get shared and one not measured in this study. All of these alternative measures of diffusion could and should be investigated.

A second limitation was the definition of exclusive versus non-exclusive. Technologies can be broadly or narrowly licensed, and thus a company may receive the exclusive rights to a technology within a narrow field of use, a scenario that arguably could be interpreted to infer almost what a non-exclusive license might do. This language was carefully investigated in this study such that if it were clear in an archival document that many narrow licenses were issued, it was coded as non-exclusive. However, it is possible that some archival sources of this information were not described accurately enough to capture this nuance. A useful way that this could be done would be for the federal government to make Inter-Agency Edison (I-Edison) data available for research purposes. I-Edison is the required reporting compliance tool through which all universities that patent a technology developed with federal funds must report including information on licensing. At present, this data is kept strictly confidential with no reports even prepared by the federal government itself that provides public insights into what is occurring nationally. Relatedly, it is important to point out that the advantage of using archival data such as we did in the study enabling the ability to investigate what was enacted contractually, rather than what a field professional says was done on a survey, is offset by the limitation of its ability to effectively capture intent as richly. Thus, future researchers using such data would be wise to link archival analysis with insights provided by persons on that campus responsible for patenting and licensing activity.

Third, this study was reliant on archival data that could be obtained through public and proprietary databases. Whereas the data in the Recombinant Capital database is among the richest sources of alliance data on the life science industry as is currently available, there were still deals that could not be used if they lacked enough information to tie a particular license to a particular patent or patents in the U.S. Patent Office database. A useful follow-up study would be to track down those deals with universities themselves to conduct the

requisite triangulation needed – although to date, most have been reluctant to disclose, citing firm confidentiality agreements.

Fourth, the field of technology commercialization continues to be a dynamic one. What were norms of practice even five years ago are evolving, particularly as new entrants to its practice begin operations. However, given the need for five years of post-deal data, the study design dictated having to use license deals that occurred no later than December of 2002. Studies of more recent deals would no doubt shed further light on trends in practice. Furthermore, it would be valuable to investigate deals in disciplines other than the life sciences to see if the same relationship patterns hold.

Lastly, the study suggests some additional fruitful paths of study. For example, principal-agent relationships could be investigated to explore a state's regulatory climate and governance structures designed to provide oversight of universities engaged in commercialization activity. Another useful pursuit could be to study the normative pressures that university technology transfer officers feel from their institutional or state policy leaders, particularly in challenged economic times when the need for new revenue flows is heightened. How are these pressures manifesting for faculty research agendas and hiring? Finally, a number of universities have signed on to a pact entitled, *In the Public Interest, Nine Points to Consider in Licensing University Technology*. This document speaks directly to the exclusive licensing phenomenon, for instance, suggesting ways that it can be better utilized without hindering access for research purposes. It also discusses other controversial practices in the field and what should be done about them. Research on the degree to which signatories, or others, are following these nine points of good practice would be informative.

Conclusion

Mitroff (1974), reflecting on the historic norms of science, once said, "For if science were also exclusively founded on the norms of disinterestedness, universalism, and community, I doubt science could have arisen as we know it. The point is that each norm is restrained and if any were unrestrained, science would probably collapse (p. 593)." This study has shown that one effect of the emergent counter-norms of secrecy and self-interestedness stimulated by a culture of commercialization and revenue generation may be a decline in traditional forms of knowledge dissemination and collaboration on project with other researchers outside one's institution, a phenomenon that appears to threaten what is broadly viewed as a key engine of innovation. These norm changes appear to be hindering innovation via the traditional mechanisms (research publication and collaboration), questioning the success of policymaking to date for the purpose of speeding its movement off the lab bench to society. Yet, the full normative implication requires additional investigation into other innovation diffusion mechanisms that may offset this reality.

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Figure 1.
Theoretical Model of Commercialization Affects on Innovation Diffusion

Table 1

Descriptive Results (n=345)

Variable	Mean	Standard Deviation
Follow-On Research: No. Inventor Publications	29.77	24.96
Follow-On Collaborations: No. of Publications with Outside Collaborators	14.53	16.02
Follow-On Collaborations: No. of Outside Collaborators	54.25	72.82
No. Inventor Pubs. w/ Outside Collaborators/Total Pubs.	.45	.25
Licensing Exclusivity	.10	.29
Technology Scope	6.73	4.34
Research Citations	37.37	42.86
Public vs. Private University	.26	.44
Inventor Previous Publications	24.55	21.65
Inventor Previous Publications w/ Collaborators	10.87	12.46
Inventor Previous Collaborators	35.95	49.89
Inventor Previous Patents	2.83	5.21
Time	10.10	3.29
No. Previous Pubs. w/ Outside Collaborators/Total Pubs.	.41	.25

Table 2

Bivariate Correlations for Control and Independent Variables (n=345)

Variable	1	2	3	4	5	6	7
1. Prev. Pubs. Coll.							
2. Prev Patents	.28**						
3. Time	-.03	-.15**					
4. Prev. Pubs. Coll./Total Pubs	.61**	.00	.04				
5. Licensing Exclusivity	.18**	.16**	-.17**	.15**			
6. Technology Scope	.05	.09	.11*	.05	.04		
7. Research Citations	.05	-.18**	-.12*	.01	-.06	-.12*	
8. Public vs. Private	-.14**	-.01	.06	.01	-.20**	.08	-.10

*
 $p < .05$;**
 $p < .01$;***
 $p < .001$.

Table 3

Hierarchical Regression Results (n=345)

Variables	Model 1: Inventor Publications		Model 2: Publications with Outside Collaborators		Model 3: Number of Outside Collaborators		Model 4: Collaborative Publications/ Total Publications	
	Partial	Full	Partial	Full	Partial	Full	Partial	Full
Prev. Pubs. Coll.	.67***	.67***	.71***	.72***	.70***	.70***		
Prev. Patents	-.02	.01	-.09*	-.07	-.15***	-.12***	-.08	-.08
Time	-.02	-.03	-.08	-.10**	-.15***	-.16***	-.07	-.10*
Prev.Pubs. Coll./Total Pubs.							.44***	
Licensing Exclusivity		-.12**		-.16***		-.14***		-.16**
Technology Scope		.01		.06		.05		.06
Research Citation		.05		.03		.08*		-.05
Public vs. Private		-.09*		-.07		.07		-.08
F-value	90.85***	41.97***	108.85***	51.75***	100.81***	48.20***	24.58***	12.45***
Adjusted R ²	.44	.46	.49	.51	.47	.49	.17	.19

* $p < .05$;** $p < .01$;*** $p < .001$.