Institutional Boundaries and Interorganizational Collaboration in the Field of Agricultural Biotechnology

ABSTRACT

We investigate the extent to which publishing by private companies and patenting by universities can be taken as evidence of a blurred institutional boundary between academic and commercial science in the field of agricultural biotechnology. Data from interviews with one hundred forty-four scientists working in the field of agricultural biotechnology reveal differences in the publishing and patenting practices of scientists employed in universities and private companies. These differences affect university and industry scientists' decisions to seek or avoid collaborations with each other. Standard university-industry agreements concerning publication delays both facilitate interorganizational coordination and formally reinforce institutional boundaries.

INTRODUCTION

Patenting by universities and publishing by private companies have been seen as relatively atypical organizational behaviors and received attention from social scientists. Walter Powell and Jason Owen-Smith have co-authored extensively on the effects of commercialization in the life sciences on universities. One jointly produced article, "Universities and the Market for Intellectual Property in the Life Sciences," analyzes the "consequences for universities of treating knowledge as intellectual property". Using data on university patenting, royalties derived from university licensing, and labor market changes for biological scientists, Powell and Owen-Smith document what they see as "the blurring of the division of labor between universities and industry" (1998: 259). They write:

> "Dasgupta and David [1987, 1994] argue that the realms of science and technology are separated more by their social organization and reward structure than by the actual character of their work. Despite the similarities and methods of their work, scientists and technologists enter their respective realms 'precommitted' to different norms and rules of the game. For scientists, priority of discovery is the goal, and publication is the means through which new knowledge is shared in a timely fashion [Merton, 1957]. The public nature of scientific knowledge encourages its use by others, and in so doing, increases the reputation of the researcher [Merton, 1988; Stephan, 1996]. In contrast, patents are the coin of the realm in the technologist's world. Rewards are pecuniary and the incentive to divulge new information quickly is not as potent.
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> Our argument is that the separation of the realms of science and technology no longer holds in the life sciences. The formerly independent, if fragile, system is today fully interdependent as universities have become much more oriented to the commercialization of research (1998: 254).

Other scholars have drawn similar conclusions, again citing publishing by industry and patenting by universities as indicative of a blurred institutional boundary between academic and commercial science. Sheila Slaughter et al report that increased university patenting, the formation of start-up companies, and partnerships with industry are evidence of the university's "move toward the market" (2004:129). Daniel Lee Kleinman and Steven Vallas see publishing in scholarly journals by industry scientists as an appropriation of traditional academic conventions by private corporations (2001: 471).

Several of these scholars use the language of organizational fields to describe the changes they see taking place in universities and industry. Kleinman and Vallas write that a "massive redrawing of institutional boundaries between basic and applied research, public and private domains, and academic and industrial organizations" has led to "an increasing convergence between previously distinct organizational fields" (2001: 452). Walter Powell et al state that the activities and pressures experienced by actors working in the life sciences in universities and private companies have become so similar that we should conceptualize these organizations as members of the same organizational field. They term this organizational field the "commercial field of biotechnology" in their upcoming *American Journal of Sociology* paper (Powell et al: forthcoming).

A "concrete system of interrelationships" between organizational actors in an institutional arena has variously been termed an organizational field, a societal sector, or an organizational community (Ruef 2000: 660). Powell et al define an organizational field as "a community of organizations that engage in common activities and are subject to similar reputational and regulatory pressures". They write that organizational fields "emerge when social, technological, or economic changes exert pressure on existing relations, and reconfigure models of action and social structures" (Forthcoming).

There are many similarities in the work of academic and commercial scientists in the field of agricultural biotechnology. Scientists employed by universities and private companies conduct basic

and applied research in the plant and animal sciences. Many of these scientists participate in interorganizational research collaborations. The research academic and commercial scientists conduct often has commercial applications. University and industry scientists' discoveries are reported in peer-reviewed publications, protected with patents, and evaluated by the international scientific community. How similar then are the pressures faced by university and industry scientists working in the field of agricultural biotechnology? To what extent are scientists' research agendas shaped by criteria related to the field in which they conduct their research, their professional socialization as scientists, or their organizational employment as academic faculty or members of private companies? Do the patenting and publishing activities of universities and private companies in the field of agricultural biotechnology indicate that little distinction remains to be made in the research orientations of these organizations?

In this paper we report data gathered from interviews with one hundred forty-four scientists who have similar educational backgrounds, conduct research related to the agricultural biotechnology field, and are employed by academic and commercial organizations. Data on the criteria these scientists use in selecting their research agendas allows for assessment of the influence of organizational employment, while controlling for professional socialization and field. Our data reveal significant differences in the reported criteria for research problem choice between scientists employed in academic and non-academic positions. We then use interview data to highlight differences between academic and industrial organizations with regard to publishing and patenting, focusing on the criteria used in decisions to release discoveries into the public domain and on the organizational actors empowered to make such decisions. We then employ case study data to explore how university-industry research collaborations are structured in light of institutional differences concerning the release of scientific information into the public domain through publications and patents. We analyze standard publication delay agreements, which we argue both facilitate interorganizational coordination and formally reinforce institutional differences between

universities and biotechnology companies with regard to publishing and patenting. Finally, we report interview data that suggest that private companies tend to collaborate with universities when they desire research publications and avoid collaborations when their intellectual property position is insecure and that university scientists may avoid collaborations with private companies if they perceive potential constraints on their ability to publish freely. Our data support Powell and Owen-Smith's argument that universities and the biotechnology industry are interdependent. We view the institutional boundaries that delineate the cultures of academic and commercial science as key in forming the basis of that interdependence.

DATA AND METHODS

The interview and case study data reported in this paper were obtained through a project funded under the Initiative for Future Agriculture and Food Systems Program of the United States Department of Agriculture's Cooperative State Research, Education, and Extension Service. The project is entitled "Public Goods and University-Industry Relationships in Agricultural Biotechnology." From April 2002 to December 2004, our project team interviewed one hundred forty-four scientists at nine universities and twenty-four private companies. Six of the universities selected are land grant universities, which represent our primary case studies. One public non-land grant university and two private universities were selected for comparison purposes. The twenty-four private companies in our sample include six transnational biotechnology corporations, four medium-sized biotechnology companies, two subsidiary companies, and twelve small biotechnology start-up companies.

The one hundred forty-four scientists in our sample have similar educational backgrounds and conduct research related to the field of agricultural biotechnology. One hundred forty of the scientists have Ph.D.s, one has a Doctor of Veterinary Medicine degree, and three have Master's degrees (these four scientists work in industry positions). Ninety-eight of the scientists in our sample are university professors and forty-six are employees of private biotechnology companies. We ask

our respondents about the mission and goals of their own and their collaborators' organizations. We ask how research collaborations are structured and about the institutional rewards associated with the publishing and patenting of research discoveries. The interviews are transcribed and coded in an Atlas database. The questionnaire data are analyzed using SPSS.

PROFESSION, ORGANIZATION, AND FIELD—WHAT SHAPES SCIENTISTS' RESEARCH AGENDAS IN AGRICULTURAL BIOTECHNOLOGY?

Using Powell et al's classification scheme for the field of biotechnology in the life sciences, one could argue that the one hundred forty-four scientists in our sample all work in the field of agricultural biotechnology. The scientists in our sample all received their training and conduct or oversee research in fields related to agricultural biotechnology. The university scientists in our sample participate in or oversee collaborations with private agricultural biotechnology companies and the industry scientists in our sample participate in or oversee collaborations with universities. Several of the industry scientists in our sample have held positions as postdoctoral fellows or faculty members in universities over the course of their careers. Many of the university scientists in our sample regularly consult for or serve on the scientific advisory boards of private biotechnology companies. Some of these university scientists also hold equity positions in start-up companies in addition to their faculty positions.

The scientists in our sample also share similar professional socialization experiences. All of our respondents completed graduate degrees in the sciences and were therefore exposed to the culture and norms of academic science. Edward Hackett describes the culture of academic science as "a blend of the cultures of science and academe" (1990: 245). In academic science, research productivity and professional accomplishment are measured by an individual's record of research publications in scholarly journals.

Hackett also makes the important observation that science "is undertaken within organizations, and organizations have unique properties, dynamics and goals" (1990: 245). Does

employment as a university professor or member of a private company matter for the research agendas and scientific output of scientists in the field of agricultural biotechnology? Is the work of these scientists shaped by the field in which they conduct their research, their professional socialization as scientists, and/or the organizations in which they are embedded? In order to assess the influence of organizational employment on the work of scientists in our sample, we asked our respondents about the criteria they use in choosing their research agendas. We asked our respondents to rate each criterion using a Likert scale from (1) "Not Important" to (7) "Very Important."

If the field of agricultural biotechnology and/or their professional socialization were key in shaping the work of scientists in our sample and the work orientation of university and industry scientists in the field of agricultural biotechnology were essentially the same, we would expect the scientists in our sample to report using similar criteria when choosing their research agendas. If there were notable differences in the work orientations of scientists based on their organizational employment in universities or private biotechnology companies, we would expect differences in the responses of the university and industry scientists in our sample with regard to the criteria they use in choosing their research agendas.

The Likert scale data from our questionnaire on the factors that influence research problem choice are presented as mean scores in **Table 1**. The responses are grouped by primary employment in an academic or industry organization in order to test for the influence of organizational employment on scientists' choice of research agendas in the field of agricultural biotechnology. These responses indicate significant differences in the criteria used by academic and industry scientists in selecting their research problems along several dimensions.

The first criterion, "Potential contribution to scientific theory," receives a score of "6" or higher from 64.6% of the university scientists in our sample. None of the university respondents rate this criterion a "1." In contrast, only 19.5% of the industry respondents in our sample rate this criterion a "6" or higher and 8.7% rate it a "1."

The next criterion, "Potential marketability of the final product," receives a score of "6" or higher from 21.9% of the university scientists in our sample. 46.9% of the university respondents assign this criterion a score of "3" or lower. In contrast, 86.9% of the industry scientists in our sample assign this criterion a score of "6" or higher. Notably, none of the industry respondents assign this criterion a score lower than "3."

These data suggest that most of the university scientists in our sample are concerned with making contributions to scientific theory when choosing their research agendas and that most of the industry scientists in our sample are concerned with developing marketable products when choosing their research agendas. The varied responses from the industry scientists in our sample to the "potential contribution to scientific theory" criterion and the varied responses from the university scientists in our sample to the "potential marketability of the final product" criterion are consistent with the institutional blurring argument. We attribute the industry scientists' interest in contributing to scientific theory partially to their socialization in academic science during their graduate educations. We attribute the university scientists' interest in contributing to the development of marketable products partially to the fact that the majority of the university scientists in our sample work in land grant universities, where applied research has historically been valued.

The differences in the research problem choice criteria reported by the university and industry scientists in our sample indicate that scientists' organizational employment in universities and private companies, in addition to their professional socialization as scientists and the field of agricultural biotechnology itself, is important in shaping the research agendas of scientists working in the field of agricultural biotechnology. These data reveal that even in fields with blurred institutional boundaries, actors appear to be embedded in organizations that shape the nature of their work.

Research that contributes to scientific theory is usually publishable in scholarly journals. Marketable products in the field of agricultural biotechnology are usually protected with patents. Data from our questionnaires suggest that university and industry scientists weigh the probability of

publishing and patenting their research discoveries differently when choosing their research problems. These data are consistent with the data reported above on how university and industry scientists rate the criteria "potential contribution to scientific theory" and "potential marketability of the final product" when choosing their research agendas.

84.4% of the university scientists in our sample assign the criterion "Publication probability in professional journals" a score of "5" or higher. None of the university scientists in our sample assign this criterion a score of "1." In contrast, 32.6% of the industry scientists in our sample assign this criterion a score of "5" or higher and 13.0% assign it a score of "1." 82.6% of the industry respondents in our sample assign the criterion "Potential to patent and license the research findings" a score of "6" or higher. Only 4.4% assign this criterion a score of "3" or "2" and none of the industry respondents assign it a score of "1." In contrast, only 3.1% of university respondents in our sample assign this criterion a score of "6", none assign it a score of "7" and 31.3% assign it a score of "1."

We found that only one of the ninety-six university respondents with reported data in our sample assign a higher score to the probability of patenting than the probability of publishing research findings and that eight assigned the same score to these two criteria. In other words, 90.7% of the university respondents in our sample assign greater weight to the probability of publishing their research discoveries than the probability of patenting their research discoveries. In contrast, only three of the forty-six industry respondents in our sample assign a higher score to the probability of publishing research findings than the probability of patenting research findings and nine assigned the same score to these two criteria. In other words, 73.8% of the industry scientists in our sample assign greater weight to the probability of patenting their research discoveries than the probability of publishing their research discoveries.

Responses to the criterion "Priorities of the research organization" begin to illuminate differences in how research agendas are set within university and industry settings and are important

for understanding institutional differences in the publishing and patenting of research discoveries. 95.7% of the industry respondents in our sample assign the criterion "Priorities of the research organization" a score of "5" or higher. None of the industry respondents in our sample assign this criterion a score lower than "4." In contrast, 44.2% of the university respondents in our sample assign this criterion a score of "5" or higher and 29.5% assign it a score of "3" or lower.

Differences in the scores assigned to this criterion by the university and industry scientists in our sample are indicative of differences in how research agendas are selected in academic and commercial research organizations. These decisions, like decisions about when to pursue publications and patents for research discoveries, tend to be made hierarchically in private companies and individually in universities. Industry decisions to release research discoveries into the public domain are strategic and intended to advance the interests of the company. University policies on academic freedom and openness in research are intended to protect the autonomy of individual faculty members in choosing their research agendas and when to pursue publications and/or patents for their research findings.

Both industry and university researchers are concerned with "getting scooped," having another scientist make a similar discovery and claim his or her stake to it first in the public domain through a publication or patent. Both university and industry scientists employ the use of secrecy to protect their discoveries before they are ready to pursue publications and/or patents. However, unlike universities, biotechnology industry organizations often employ the use of trade secrets and confidentiality agreements in order to keep knowledge inside the firm. Bert Spilker explains incentives to delay putting a new discovery into the public domain in the biotechnology industry: "The natural tendency of scientists, and even companies, when they have made a major discovery is to apply for a patent to protect their invention. But they know they will have a greater degree of protection and greater chances of success" if they conduct further research and are more able to describe the biological activities and properties of newly discovered organisms or genes prior to

filing for patent protection (1994:620). The reason has to do with satisfying one of the three criteria involved in obtaining a new patent. The inventors must demonstrate the utility, or practical application, of the new discovery. Often in biotechnology research, at the early stages of discovery, the potential applications of a gene or genetically modified organism are not fully known.

There are other reasons for waiting to file a new patent application. The U.S. government gives the inventor the right to control the property in exchange for a full and complete disclosure of the invention. Information about the invention becomes public eighteen months after the first filing date of the patent. Sometimes firms will complete the initial patent filing and then rush to complete additional research during that eighteen-month period. In other cases firms delay public disclosure of their discoveries until they are ready to bring their product to market. This is because information about their discoveries might aid competitors in developing a similar product that might reach the market first (Spilker 1994). Therefore, rather than pursue immediate intellectual property protection for their discoveries, private biotechnology companies often choose to keep valuable information inside the organization. Decisions to publish or patent research outcomes are made with greater concern for the long-term profitability of the company than an individual industry scientist's career.

In our interviews, many of the industry scientists in our sample report that they are allowed to publish, but that conducting research without likely commercial relevance is not encouraged. Several report not having the time to prioritize publishing activities. Some report publishing within industry to be regarded favorably by their organizations; others report it is treated somewhat neutrally. Publishing is usually undertaken only after intellectual property concerns are addressed and scientists must receive approval from their companies prior to publishing their findings.

One of our industry interviewees, a research scientist at a biotechnology start-up company, described publishing as a "luxury," an activity he normally does not have time to pursue as part of his central employment responsibilities. He believes his company would reward him for publishing, but that it is something to be completed on his own time, outside of normal working hours. This

interviewee also notes that he must get approval from his company prior to publishing and that he may be required to delay pursuing a publication until the company feels its intellectual property position is secure.

Several of the university scientists in our sample describe patenting in the same way many of the industry scientists in our sample describe publishing—as a favorably viewed side activity, but not a central work responsibility or condition of employment. For example, a professor at a land grant university told us that patents tend to reflect work that a university scientist has also described in a scholarly publication. Others report that a lack of patenting activity would not be counted against a faculty member and that patenting in the absence of publishing would be viewed negatively.

We asked the university scientists in our sample whether or not they had patented any of their research discoveries and if so, why. Disclosing potentially patentable research discoveries was often described as an obligation—to one's university, industry collaborator, or both. Some university scientists cite compliance with federal laws as a driving factor. In contrast, intellectual property concerns actively shape the research agendas of scientists working in industry. Our industry respondents often report that their research is aimed at developing a secure intellectual property position and that they will not publish their research findings until they can achieve it.

Decisions concerning when and whether to patent or publish research discoveries are made hierarchically in agricultural biotechnology companies and are not left to individual scientists' discretion. When agricultural biotechnology companies allow their scientists to publish their research findings, there are often strategic motivations, such as recruiting or retaining top scientists, attracting capital from investors, or aiding in the pursuit of regulatory approval for a company product. For example, a research coordinator at a multinational biotechnology corporation stated that collaborating with universities and putting research results into the public domain are useful for gaining credibility in the eyes of regulators. Interestingly, this interviewee also mentioned that his company was concerned with whether or not they were "publishing too much." This concern relates

to potentially aiding their competitors by sharing information in the public domain. "Publishing too much" was not a concern voiced by any of our university respondents. Instead, the university scientists in our sample frequently discussed the importance of publishing during our interviews. Publications are cited as an important benefit of university research and a primary means of making the results of collaborations available to the public, which university scientists view as consistent with their organizational mission.

These data from interviews with university and industry scientists reveal differences in the organizational actors empowered and the criteria used to make decisions concerning research agendas and when to release scientific discoveries into the public domain through publications and patents. In light of these differences, how do university and industry scientists structure their research collaborations with each other?

MANAGING INSTITUTIONAL DIFFERENCES IN UNIVERSITY-INDUSTRY RESEARCH COLLABORATIONS

Studies of interorganizational collaboration in knowledge-intensive fields like biotechnology have tended to focus on linkages between organizations with similar goals and orientations. For example, in "Learning from Collaboration: Knowledge and Networks in the Biotechnology and Pharmaceutical Industries," Powell describes the "learning race" experienced by actors in technologically-intensive fields. The "pervasive concern with access to knowledge" in rapidly evolving fields like biotechnology contributes to "large-scale reliance on interorganizational linkages" (1998: 229). Similarly, AnnaLee Saxenian contends that decentralized cooperative and competitive networks contributed to the success of Silicon Valley engineers. Both of these studies examine collaboration between private sector organizations oriented toward the development of new products and the maximization of organizational profits. Conflicts relating to delays in the publication of collaborative research findings are unlikely to arise in private sector interorganizational collaborations.

Less attention has been devoted to how actors embedded in organizations with qualitatively different organizational goals structure their interorganizational collaborations and why private companies collaborate with universities, beyond obtaining access to knowledge and expertise. In this section, we analyze standard publication delay agreements in university-industry research collaborations, which we argue both facilitate interorganizational coordination and formally reinforce institutional differences between universities and biotechnology companies with regard to publishing and patenting. We also investigate what factors lead university and industry scientists to seek or avoid collaborations with each other.

Scott et al write that organizations need social acceptability and credibility, in addition to material resources and technical information, in order to survive. Organizational legitimacy is achieved through alignment to "normative, regulatory, and cultural-cognitive rules and beliefs" in the social environment (2000: 236). Meyer and Rowan similarly assert that organizations that shape their practices and procedures to be consistent with institutionalized rules increase their legitimacy and survival prospects (1991).

Most of the funding universities receive to support their research activities comes from public sources. Universities are classified as non-profit institutions. Nonprofit organizations are expected to take an institutional form that differs from those of for-profit organizations. In other words, "a nonprofit organization is a different type of institution from a private firm either because the constraints on it differ or because its objectives differ or both" (Weisbrod 1998: 71). If universities were to modify their research practices and procedures such that they were indistinguishable from those of private industry by perhaps directing their scientists to delay publication of research results until further research might ensure stronger patent applications or by approving university-industry collaborative agreements with such stipulations, universities would jeopardize their institutional legitimacy.

Not only do universities not instruct their scientists to delay the publication of their research findings in order to pursue stronger intellectual property positions, they have developed policy statements that proclaim their commitment to the open dissemination of research results. These policy statements aim at reinforcing the institutional status of universities as knowledge-producing organizations insulated from the market. However, recognizing that industry organizations are unlikely to engage in research collaborations with university scientists if they cannot patent the outcomes prior to publication, universities frequently allow research agreements to be made which stipulate thirty to ninety-day delays in the publication of research results, the time period generally deemed sufficient to pursue intellectual property protection for a joint research finding.

University declarations of refusal to allow research agreements that stipulate extended delays in the publication of research outcomes can be interpreted as organizational "ceremonial conformity" to institutionalized rules (Meyer and Rowan 1991: 41). Limited publication delays of thirty to ninety days can be viewed as an interorganizational compromise, a way of mediating the differences in university and industry actors' orientations toward the publishing and patenting of their research discoveries. Industry scientists expect their university collaborators to contact them before publishing findings from research collaborations and often stipulate this at the outset of collaborations. This condition is often the only expected return when companies provide university scientists with materials, equipment or funding to conduct research. Agreements often stipulate that an industry partner will be allowed a brief time period to pursue intellectual property protection for joint research discoveries.

In our view, these agreements represent an organizational form, as defined by Elisabeth Clemens. She writes that organizational forms are "a part of our 'cultural toolkit'". They are "a set of familiar patterns for ordering social relations and action". As a form of cultural competence, mutual knowledge of a given form can facilitate cooperation, allowing reliance on tacit understandings rather than explicit instruction. Shared mastery of organizational forms "facilitates

collective action" (1997: 48-50). We also see this organizational form as a boundary object, as defined by Star and Griesemer. They describe boundary objects as "both plastic enough to adapt to local needs and the constraints of several parties employing them, yet robust enough to maintain a common identity across sites" (1989: 393). Lamont and Molnár write that boundary objects "can be material objects, organizational forms, conceptual spaces or procedures." Though boundaries are often treated as markers of difference, boundaries can also be conceptualized as "interfaces facilitating knowledge production" (2002: 180).

A mutual awareness of university and industry orientations toward publishing and patenting shape these organizations' patterns of interaction. Sometimes they spur interaction and sometimes they cause university and industry scientists to avoid collaborating. For example, a scientist at a land grant university told us that he would choose to not collaborate with a private company if he could not fulfill his obligations to publish.

Though industry collaborators may seek to exert personal pressure on their university collaborators in the absence of enforceable contractual agreements concerning publication delays, they may often simply choose to avoid collaborations with university scientists. For example, a senior scientist at a biotechnology start-up company told us that his company limits information exchange with university researchers and sometimes avoids collaborations in order to guard against the potential loss of intellectual property. Similarly, a research scientist at another biotechnology start-up company voiced the concern that collaborating with universities might result in the release of information that could aid competitors. Companies tend to collaborate with universities when they want to release information into the public domain. Companies often collaborate with universities when they hope publications will emerge from the collaborations. These publications may aid a company in gaining regulatory approval for a product or in attracting investment or top scientists to their organization. Industry scientists in our sample also mention the potential marketing benefits of

collaborating with universities when they desire acceptance of new agricultural biotechnology products by growers and the public.

Our interview data indicate that university and industry scientists recognize institutional differences between their own and their collaborators' organizations with regard to releasing scientific information into the public domain and that they tend to seek collaborations only when both parties are oriented toward the open communication of research results.

CONCLUSION

Biotechnology has been described as a field in which academic and commercial organizations are subject to similar institutional pressures and produce common outputs. In addition, the fact that scientists who conduct research in this area often move between for-profit and non-profit organizations over the course of their careers and frequently collaborate with or work for organizations in both sectors simultaneously has left the influence of organizational employment on scientists' research agendas open to question. In this paper we have investigated the extent to which publishing by private companies and patenting by universities can be taken as evidence of a blurred institutional boundary between academic and commercial science in the field of biotechnology.

Data from interviews with scientists employed in universities and biotechnology companies about the criteria they use in choosing their research problems indicate that scientists working in the field of agricultural biotechnology are embedded in organizations that shape the nature of their work. Industry scientists in our sample tend to prioritize research aimed at producing patentable discoveries and marketable products over contributions to scientific theory and scholarly publications, and the reverse tends to be true for the university scientists in our sample. In addition, decisions concerning research agendas and the timing of the release of scientific discoveries into the public domain through publications and patents tend to be made individually in universities and hierarchically in private companies. These findings reflect differences in the institutional cultures of academic and commercial science.

Publishing and patenting decisions are made strategically in industry organizations. Biotechnology companies regularly use confidentiality agreements and trade secrets to keep knowledge inside the firm. They can compel their scientists to delay releasing discoveries into the public domain, sometimes in order to pursue research that may broaden the scope of intellectual property protection and sometimes to avoid aiding competitors. Biotechnology companies may publish in order to attract investment and scientific talent. They often engage in collaborations with university partners when they desire publications that might aid their product in gaining regulatory approval or adoption by growers and avoid collaborations when their intellectual property position is insecure. These collaborations reflect the interdependence described by Powell and Owen-Smith.

In contrast, decisions about research agendas, whether or not to collaborate with outside organizations and when to publish and patent discoveries are made at the individual, rather than organizational level in universities. Though most research universities have technology transfer offices and encourage their faculty to disclose their findings prior to publishing, the choice of when to publish a research discovery rests with the individual faculty member. Universities do not compel faculty members to pursue additional research that might foster stronger patent applications prior to publishing. On the contrary, university policies concerning academic freedom are designed to preserve faculty autonomy in decisions about when to release scientific discoveries into the public domain. These policies govern university-industry collaborative agreements. Though an industry collaborator may request a university scientist delay publication for a brief period of time in order to pursue intellectual property protection for a discovery, the collaborator also cannot compel a university scientist to conduct or allow time for further research prior to publishing a discovery.

Industry organizations have no formal or legal means to compel a university collaborator to delay publication of a research finding until additional research that might strengthen a patent application can be completed. Universities tend to block agreements that stipulate anything beyond a

university scientist informing the industry collaborator prior to publishing and allowing a brief period of time to file for intellectual property protection.

The differences in the orientation of academic and commercial scientists with regard to releasing scientific discoveries into the public domain presents an organizational challenge for university-industry collaborations. Standard thirty to ninety-day publication delay agreements serve to mediate these institutional differences. We argue that these agreements both formally reinforce institutional differences between academic and commercial organizations in the field of biotechnology and facilitate collaboration between organizations with different orientations toward publishing and patenting.

Though these agreements may largely preserve university scientists' autonomy with regard to publishing decisions in a formal sense, they do not necessarily provide much leverage when industry collaborators exert personal pressures to delay by appealing to norms of reciprocity. However, rather than resort to this uncertain and relatively illegitimate means to influence their university collaborators, companies tend to avoid collaborations when their intellectual property position is insecure and only collaborate when they hope publications will emerge from their collaborations with universities. Similarly, rather than be subjected to such pressures, some university scientists may choose to limit their collaborations with private companies if they perceive potential difficulties concerning publishing may emerge.

Rather than evidence of a blurred institutional boundary between academic and commercial science, publishing and patenting by universities and agricultural biotechnology companies, when closely examined, reveal differences in the institutional cultures of these organizations. These differences contribute to their interdependence. Differences in the institutional cultures of academic and industrial organizations have implications for how scientists working within them choose their research agendas, when and why they publish and patent their research findings, and when and why they engage in university-industry collaborations.

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Table 1: University and Industry Respondents' on the Criteria They and Their Organization's Scientists Use in Choosing their Research Agendas

Variable	University Respondents (Mean) N: 96	Industry Respondents (Mean) N: 46
Potential contribution to scientific theory	5.76	3.87
Potential marketability of the final product	3.65	6.50
Publication probability in professional journals	5.88	3.80
The potential to patent and license the research findings	2.66	6.04
Priorities of the research organization	4.09	6.17

Mean score based on seven-point scale (1 = Not Important, 7 = Very Important)