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Beyond the stars: The impact of affiliation with university biotechnology centers on the industrial involvement of university scientists

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Abstract

Most study of university–industry interactions in biotechnology emphasizes the productivity (e.g., patents, spin-off firms) of a relative few number of "star" university scientists. This study uses a national survey of university scientists to assess the industry involvement of university scientists who affiliate with university research centers focused on biotechnology. The results demonstrate such affiliation to correlate positively with informal interactions with industry, such as knowledge exchange, but not with reports of the production of economic and bibliometric outputs. Implications for policy and centers programs are discussed.

Keywords: University research centers; Biotechnology; University–industry interactions

1. Introduction

In a 1984 issue of *Science*, an article entitled "Unusual Partners Launch a Biotechnology Venture" (Marjorie, 1984) reported on the establishment of the Center for Advanced Research in Biotechnology, a university-based research organization dedicated to basic science in biotechnology that operates still today. The partners include the University of Maryland, the National Institutes of Health, and several private biotechnology firms. Two decades ago, this tripartite union was deemed "unusual" because rare for the times were collaborative research centers that were university-based, multi-discipline, and especially multi-sector. Such centers, in fact, did not become commonplace until after the advent and eventual successes of the National Science Foundation (NSF) Engineering Research Centers Program in 1985.[1] Today, however, this type of integrated research approach is frequently the starting point for policy makers looking to solve large-scale science and technology problems, particularly for biotech.

It should be no surprise that the field of biotechnology was a forerunner in the establishment of "multi-purpose and multi-discipline" university research centers, organized research units which bring together scientists and engineers from industry and universities and sometimes from federal laboratories to work at the frontiers of, and in the case of biotech the convergence of, engineering and basic science. By definition, biotech is knowledge intensive and the complementary processes of discovery and innovation necessitate the union of assets that naturally characterize different types of organizations, public and private (Feldman, 2002).

There has been no shortage of study of these complementarities. Hagedoorn (1993) demonstrates that from 1980 to 1988 the biotechnology field generated significantly more research alliances than did any other field of research; Fisher (1996), moreover, identifies for the period from 1988 to 1996 the establishment of more than 20,000 small firm biotech research alliances, with a growth rate in such alliances of 25 percent per annum. However, despite the indispensable role that universities play in biotech research and development (Murray, 2002; Feldman, 2002; McMillan et al., 2000), relative few studies assess the multiple effects of universities' and university scientists'

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[1] Bozeman and Boardman (2003) contrast "multi-purpose multi-discipline university research centers" with the traditional university research center and academic departments, which tend to be more disciplinary and single-problem focused.

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biotech and biotech-related activities and research. What studies exist focus on the spillover effects of such activity, mostly in the form of small firm start-ups (Audretsch and Stephan, 1996; Zucker et al., 1998a, b), mostly with regard to the proximity of these firms to "star" university scientists (Zucker and Darby, 1996; Zucker et al., 1998a, b).

Certainly there is more to assess regarding the complementarity of university-based biotechnology research and development and industrial activities than elite university scientists at elite universities somehow and only sometimes fomenting or encouraging the entry of new firms into the biotech marketplace? This study focuses on the impact of affiliation with a university-based biotech research center (hereafter "university biotech center") on the industry interactions of university scientists, using data from a national survey of university scientists merged with an ancillary data set tracking institutional-level variation across the centers with which respondents indicated affiliation. The general hypotheses guiding the study are (1) that biotech center scientists are more involved with industry than are their non-biotech but center affiliated counterparts, and (2) that they are involved in many ways that do not directly translate into the discrete outputs or outcomes emphasized in previous study, like patents and spin-off firms (Audretsch and Stephan, 1996; Zucker et al., 1998a, b). The findings support these hypotheses, but only for certain types of university biotech centers.

This effort is organized as follows. The next section is a review of related studies focused on research alliances in biotech (regardless of sector) and on university scientists' roles in the creation of new biotech firms. The next section introduces the data, the most recent survey of university scientists by the Research Value Mapping Program at Georgia Tech. The following section presents the variables and hypotheses and uses OLS and Logistic regressions to examine the "industry involvement" of university scientists who affiliate with university biotech centers using both a composite scale of industry interaction as well as indicators for discrete types of industry interaction. The final section discusses the policy implications of the findings and provides some concluding remarks about the weaknesses of the study and areas for further research of the biotech activities of university scientists.

2. Previous study of university biotech activities

Previous study focuses on the organization and outcomes of biotech research and development (R&D). Only a handful of these studies consider university-based biotech activities. Further, no study considers university biotech centers. This section reviews the studies that consider, however, minimally or indirectly, the role that universities play in biotech R&D. Though there is much research on the patent and citation rates of private firms, these studies are excluded since they do not address the university role in biotech R&D. Studies of antecedents and correlates of university scientists' collaborations with industry are discussed in the context of the hypotheses in the following section.

2.1. The organization of biotech R&D

Most studies of the organization of biotech R&D emphasize strategic research partnerships between private firms, with only a few addressing the roles of universities as partners to firms. Feldman (2002) reviews much of the literature on these partnerships. He identifies three important actors in biotech research partnerships: small firms, large firms, and universities. Feldman further observes that most studies of these partnerships arrive at two conclusions: (1) strategic research partnerships in biotech are beneficial to private firms and (2) the partnering firms form "thick" networks with numerous types of organizations, universities included, to advance their respective research agendas. However, most of this research focuses on private firms, with just a few of the biotech research partnerships studied addressing the role of universities or university researchers (Table 1).

Some of these studies assess the composition of research networks for many areas of scientific inquiry, including biotech, and conclude that biotech networks are more likely to include universities than are partnerships in other fields (Peters et al., 1998). Cockburn and Henderson (1998) use case study to demonstrate that research networks in biotechnology see universities interacting with private companies in ways that extend beyond the "spillover heuristic." These studies are reviewed further to explain the hypotheses for the regression analyses below. However, the majority of studies on biotech R&D emphasize discrete scientific outputs, like patents.

2.2. Universities' discrete contributions to private firms

Empirical study shows the inclusion of universities in biotech research partnerships to correlate positively with a variety of outcomes for private firms. Powell et al. (1996) and Zucker et al. (1998a) demonstrate that when universities or university scientists are nodes in the biotech research partnerships of private firms, those firms' growth rates are higher than are the growth rates of firms with no university ties. Stuart et al. (1999) find the same result with respect to firms' initial public offerings whereby firms partnering with universities have higher offerings than firms that do not partner with universities. Audretsch and Stephan (1996) and Zucker et al. (1998b) associate university proximity with the establishment of new biotech firms. Arora and Gambardella (1990) demonstrate that large firms engaged in research agreements with universities have a higher incidence of agreements with other private firms and also a higher investment of capital stock in small firms. Baum et al. (2000) demonstrate that small biotech start-ups with university alliances (at founding) have higher patenting rates and higher revenue growth. McMillan et al.

Table 1
Literature on strategic research alliances in biotech

Author(s)	Focal unit of analysis: universities or private firms?	Alliance composition: universities included?
Arora and Gambardella (1990)	Private firms	Yes
Audretsch and Stephan (1996)	Private firms	Yes
Baum et al. (2000)	Private firms	Yes
Bower and Whittaker (1993)	Private firms	No
Chang (1998)	Private firms	No
Cockburn and Henderson (1998)	Private firms	Yes
Deeds and Hill (1996)	Private firms	No
Deeds, DeCarolis and Coombs (1999)	Private firms	No
Estades and Ramani (1998)	Private firms	No
Fildes (1990)	Private firms	No
Kogut, Shan and Walker (1992)	Private firms	No
Lerner and Merges (1998)	Private firms	No
Mang (1998)	Private firms	No
McMillan et al. (2000)	Private firms	No
Peters et al. (1998)	Private firms	Yes
Pisano (1990)	Private firms	No
Powell et al. (1996)	Private firms	Yes
Prevezer and Toker (1996)	Private firms	No
Senker and Faulkner (1992)	Private firms	Yes
Shan, Walker, and Kogut (1994)	Private firms	No
Stuart et al. (1999)	Private firms	No
Zucker and Darby (1996)	Private firms	Yes
Zucker and Darby (1997)	Private firms	Yes
Zucker et al. (1998a, b)	Private firms	Yes

(2000) also find higher patenting rates for private firms that collaborate with universities.

While all of these outcomes, especially patents, are certainly important for firms' success in the biotech industry (Audretsch, 2001, Liebeskind et al., 1996), they explain little about universities' contributions towards the advancement of biotech. The studies that consider universities do not explain much about universities' roles and biotech activities. What few studies that consider how universities contribute to the successes of private firms in the biotech industry emphasize providing knowledge such as new techniques and access to R&D workers, including students (Peters and Fusfeld, 1982; Faulkner and Senker, 1995). These and like exchanges are more likely as the geographical proximity of universities to biotech firms increases (Audretsch and Stephan, 1996; Zucker and Darby, 1996).

3. Hypotheses

This study employs the "meta hypothesis" that affiliation with a university biotech center is positively correlated with industry involvement. By definition, biotech is knowledge intensive and the complementary processes of fundamental research and innovation and technology development necessitate "the union of assets that naturally characterize different types of organizations," particularly between universities and private firms (Feldman, 2002, p. 4). Moreover, numerous studies (discussed directly above) demonstrate a positive impact of university ties on private firms' economic- and output-based performance, which existing and emerging firms may be aware of given the salience of some of these "successes," for instance the university–industry ties in biotech involving "star" scientists and spin-off firms (Zucker and Darby, 1996). And in times of "steady state" funding (Ziman, 1994) and "academic capitalism" (Slaughter and Leslie, 1997) university scientists engaged in industry-related research and development, including but not limited to biotech R&D, are interacting more with private firms than they have in the past (Gibbons, 1994; Etzkowitz, 1998).

The expected positive correlation between affiliation with a university biotech center and industry involvement is deconstructed into two hypotheses:

H1. Affiliation with a university biotech center that is not part of an NSF centers program is positively correlated with industry involvement.

H2. Affiliation with a university biotech center that is part of an NSF centers program has a stronger positive correlation with industry involvement than does affiliation with a non-NSF biotech center (H1).

Due to tremendous institutional heterogeneity across university research centers—in terms of intra- and extra-university relations, organizational missions including research but also non-research missions like transfer and outreach, research foci ranging from single-discipline fundamental science to prototype development for emergent industries, and (perhaps most important) funding (Bozeman and Boardman, 2003; Boardman and Bozeman, 2007)—it is reasonable to expect differences in the levels and types of industry involvement among university scientists' affiliated with university biotech centers. To distinguish between university biotech centers with ties to a NSF centers program from those without such ties is, generally, to separate university biotech centers with relatively large budgets and ambitious missions that include not only the conduct of biotech R&D but also the generation of intellectual property, new firms, and other discrete forms of technology transfer from university biotech centers with smaller budgets and fewer transfer requirements, if any. While certainly there may be exceptions whereby a university biotech center that is not affiliated with a large centers program is comparable to those that are in terms of both budget and mission, the distinction provides a defensible proxy (Bozeman and Boardman, 2004).

4. Data and variables

The data for this project comes from a national survey of university researchers, conducted from fall 2004 to summer 2005 by the Research Value Mapping Program at Georgia Tech. The survey targeted tenured and tenure-track university researchers employed in doctorate granting research extensive institutions, as defined by the Carnegie Classification (Carnegie Foundation for the Advancement of Teaching, 2004), though for alternate research purposes some EPSCoR university[2] and HBCU faculty were included. The sample was stratified by academic discipline, academic rank, and gender. The resultant sampling frame contained 4916 individuals. The survey was executed in accordance with Dillman (2000)'s "tailored design method." The survey was terminated with a response rate of 38 percent.

After removing from the sample sociologists (to compare engineers to a reference group of non-engineer, "hard" scientists) and faculty employed at EPSCoR universities and HBCUs (to compare faculty working at "research extensive" universities only), the final *N* for this data set is 1647 university researchers. From this set of scientists, 40 percent indicated affiliation with a center. Since of primary interest in this paper is the effect of center heterogeneity (e.g., biotech or not) on activities of center affiliated scientists, this subset of the sample is what the below analysis of the impact of center stakeholder heterogeneity on academic time allocations is based on.

This subset of the data should be interpreted as representative for the general population of scientists who affiliate with research centers. It is important to stress that this study is not a study of a specific breed of scientists (e.g. the personnel of a broadly defined set of centers, many of which would be non-tenure track research scientists), but a study of the implications of affiliations with centers with different stakeholders for the typical tenured or tenure track scientist from the general population of scientists who affiliate with such centers. Since the center-level variables only apply to scientists who are actually affiliated with such centers, this permits disaggregating the effects of center affiliation on scientists and assessing the relative influence of the variation in center characteristics over different academic activities.

4.1. Dependent variables

The data contain binary variables indicating how (if at all) university scientists have engaged with industry during the 12 months preceding survey response, including whether the respondent:

- Acted as a formal paid consultant to a private company.
- Placed graduate students or post-docs in industry jobs.
- Worked at a company in which he or she is an owner, partner, or employee.
- Performed work with industry directly contributed to a patent or copyright.
- Performed work with industry directly contributed to the public–private transfer or the commercialization of technology or applied research.
- Co-authored a paper or papers with industry researchers in a journal or in refereed proceedings.

A composite measure of these variables that weights each of the above types of industry interaction according to the sample frequency of the respective activities was calculated to render a singular indicator of "industrial involvement." Bozeman (2005) created this scale using as weights the inverse of the sample means for each industrial interaction item. To illustrate, because 6.8 percent (.068) of the sample has worked on a patent or copyright with someone from industry, the assigned weight for the activity is .932, a relatively "high" weight given the infrequency of the activity for the sample. Similarly, 44.6 percent (.446) of the sample report having shared their research with someone from industry, yielding a lower weight of .554, because the activity is more common. The "Industrial Involvement Scale" sums the weights for all industry interaction types included in the survey. For the present sample of scientists working in university research centers, the Industrial Involvement Scale ranges between 0 and 6.31 with a mean of 1.33.

4.2. Independent variables

The first independent variable is a binary variable coded "1" if the university research center with which the respondent indicated affiliation on the survey is a university biotech center, zero otherwise. It is important to note that survey respondents were asked only to indicate if they affiliate with a university research center and, if so, to list the name and Web URL of the center.[3] The survey did not ask respondents if the center was a biotech center. From the list of centers, each center Web site was searched to determine whether the center was "biotech or not." A center was coded as "biotech" if the center indicates (on its Web site) as areas of research biotechnology, biomedical technology, and/or nanoscale technology for biological systems. Multiple coders were used to ensure the reliability

[2]US Department of Energy Experimental Program to Stimulate Competitive Research (http://www.sc.doe.gov/bes/EPSCoR/).

[3]Respondents whether they affiliated with a university research center based on the definition: "a research institution that has five or more faculty and postdoctoral researchers and includes participants from more than one academic department." The definition was intentionally broad, given the lack of systematic characterization of centers in the literature (Bozeman and Boardman, 2003).

of the measure. The correlation among the coders this variable was .89.

The second independent variable is a binary variable coded "1" if the university research center with which the respondent indicated affiliation on the survey is a university biotech center that is part of a National Science Foundation (NSF) centers program, zero otherwise. A center was coded as "NSF biotech" if the center met the above discussed coding criteria plus was sponsored by one of the major NSF centers programs, including the Engineering Research Centers, Science and Technology Centers, Materials Research Science and Engineering Centers, and Industry–University Cooperative Research Centers programs. The correlation among the coders for this variable indicates reliability, at .92.

4.3. Control variables

Numerous variables are included in the below regression analyses to control for spuriousness, including tenure status (coded 1 if the respondent is tenured, zero otherwise), the percentage of total average weekly research time the respondent reported that she devotes to non-industry supported research, the total number of collaborators the respondent indicated having active projects with at the time of the survey, and academic field.

5. Results

OLS regression was used to examine the effects of affiliation with a university biotech center on respondents' Industrial Involvement Scale scores. The output demonstrates affiliation with a NSF biotech center to increase industry interaction. Affiliation with a university biotech center that is not a NSF center does not demonstrate a statistically significant effect. The reference group for the OLS output is comprised of physical scientists who, at the time they responded to the survey, are untenured, spend no time working with industry, collaborate with no one, and who work in "non-biotech" university research centers (Tables 2a and b).

The beta weight for affiliating with an NSF biotech center is positive and significant at the 5 percent level. The model explains about 19 percent of the variance in the relationship between the predictor variables and the Industrial Involvement Scale, with the controls for having tenure and for holding a Ph.D. in engineering or computer science being positive and highly significant predictors. Holding a Ph.D. in mathematics is negative and highly significant.

Logistic regression was used to analyze the effects of working in a university biotech center on the discrete types of industry interactions used to create the Industry Involvement Scale. These models employ the same independent and control variables. The below table includes only the models with statistically significant results

Table 2a
OLS regression results predicting the "industrial involvement" of university scientists working in university research centers

	Standardized coefficients	Std. errors	*T*-scores	Sig
Biotech	−.037	.029	−1.004	.316
NSF biotech	.076**	.408	2.128	.034
Tenured	.137***	.115	3.871	.000
Percent non-industry	−.044	.003	−1.238	.216
Total collaborators	.058	.001	1.641	.101
Life Science	−.046	.218	−1.038	.300
Ag. Science	.041	.353	1.069	.285
Comp. Science	.117***	.261	2.958	.003
Engineering	.340***	.161	6.645	.000
Bioengineering	.036	.987	1.011	.312
Math	−.097***	.283	−2.497	.013
(Constant)		.348	2.807	.005

Note: Standard errors are in parentheses. Significance levels denoted by *(10 percent), **(5 percent), ***(1 percent or better).

Table 2b
Model summary

Model	*R*	R^2	Adjusted R^2	Std. error of the estimate
1	.433	.188	.173	1.36206

Table 3
Logistic regression results for discrete types of industry interaction on university biotech center and NSF university biotech center affiliation

	Query from industry	Contacted industry	Tech transfer
Biotech	−.052	−.15*	−.17*
	(.051)	(.080)	(.094)
NSF biotech	2.38**	1.67**	.28
	(.955)	(.690)	(.739)
Tenured	.71***	.73***	.58**
	(.195)	(.234)	(.239)
Percent non-industry	−.002	−.01	−.004
	(.006)	(.006)	(.005)
Total collaborators	.044***	.02***	.0002
	(.010)	(.008)	(.001)
Life Science	−.203	.16	−.05
	(.386)	(.495)	(.542)
Ag. Science	.89*	.65	.94
	(.543)	(.622)	(.628)
Comp. Science	1.01**	1.00**	1.50***
	(.412)	(.477)	(.475)
Engineering	1.55***	1.35***	1.11***
	(.272)	(.334)	(.354)
Bioengineering	−2.26	−1.26	
	(1.78)	(1.56)	
Math	−2.49**	−1.48	−1.36
	(.284)	(1.070)	(1.06)
R^2	.178	.126	.061
N	679	677	649

Note: Standard errors are in parentheses. Significance levels denoted by *(10 percent), **(5 percent), ***(1 percent or better).

Table 4
Post-LOGIT calculation of marginal effects (using STATA MFX compute)

	Query from industry	Contacted industry	Tech transfer
Biotech	−.01	−.02*	−.02*
NSF biotech	.54***	.25*	0.3

Note: Only values for university biotech center affiliation reported. Actual post-LOGIT calculations included the entire model specification from Table 3. Significance levels denoted by *(10 percent), **(5 percent), ***(1 percent). The dy/dx values reported for a discrete change in dichotomous variable from 0 to 1. Values of all dichotomous control variables held at zero; all continuous control variables held at their respective means.

for the binary variables indicating affiliation with either a non-NSF or a NSF university biotech center (Table 3).

The output demonstrates that being affiliated with a university biotech center that is not a NSF center negatively affects the log odds of having contacted industry personnel asking about their research. This variable has the same effect on the log odds of working directly with industry personnel to transfer or commercialize technology or applied research. The findings further demonstrate that being affiliated with a NSF university biotech center increases the log odds of being contacted by persons from a private company about one's research. This variable has the same effect on the log odds of having contacted industry personnel about their research.

Post-estimation marginal effects for the Logistic regression models were calculated (Table 4).

Affiliation with a non-NSF university biotech center decreases by two percentage points the probability of contacting industry personnel about their research. This variable has approximately the same effect on the probability of helping industry personnel to transfer technology or applied research. Affiliation with a NSF university biotech center is associated with a much higher probability of contacting industry personnel about their research, 54 percentage points higher, and of being contacted by industry for the same reason, which is 25 percentage points higher.

6. Discussion

Limiting the discussion to results that were statistically significant at the 5 percent level or better, the output of the OLS regression (using the Industrial Involvement Scale as the dependent variable) confirms the second hypothesis, that NSF university biotech center affiliation correlates positively with industry involvement; but the output disconfirms the first hypothesis, that affiliation with a university biotech center that is not tied to a NSF centers program correlates positively with industry involvement. Similar but more specific, the Logistic outputs disconfirm the first hypothesis but confirm the second hypothesis by demonstrating affiliation with a NSF university biotech center to increase industry involvement in specific ways: by increasing the likelihood of a scientist being contacted by industry about her research as well as the likelihood of a university scientist contacting an industry scientist about firm-based research.

6.1. Hypothesis 2: confirmed

First, these results suggest that programs such as the NSF Engineering Research Centers program are succeeding in fulfilling the mission of cross-sector interaction, at least for biotech R&D. The results suggest that NSF university biotech centers facilitate networking behaviors between university scientists and industry personnel but are less effective regarding the generation of tangible outputs such as patents and commercial technologies. These results may serve as indirect evidence that university research centers are succeeding in the mission to encourage knowledge flow but are perhaps failing somewhat to achieve other goals related to development of the emergent biotech industry.

6.2. Hypothesis 1: disconfirmed

Second, that scientists affiliated with university biotech centers with no programmatic ties to the NSF engage with industry at about the same rate as scientists affiliated with non-biotech other centers do seems surprising in light of discussion of university roles in biotech R&D. But it is perhaps less surprising once one considers the comparative base. The centers to which biotech centers are compared are most often ones dominated by engineering, computer science and materials science, all fields with long-standing commercial applications and extensive histories of close cooperation with industry. It is also worth noting that many of the comparison centers were set up explicitly because of a lag in industry R&D. In the case of the biotechnology centers, the firms that are their potential partners are themselves spending substantially on R&D, not only at a much higher rate than firms in almost all other fields, but also at a rate about 30 times that of universities. So there is limited drive to partner with universities as a substitute for in-firm R&D. Non-NSF university biotech centers, generally, do not benefit from as large an annual budget and are not subject to the NSF mandate for industry interaction.

7. Conclusion

This paper demonstrates that scientists affiliated with NSF centers program-based university biotech centers are involved with industry in ways different than "star" scientists have previously been demonstrated to be involved. Rather than establish start up firms and engage in the production of commercially relevant outputs like patents and copyrights (Audretsch and Stephan, 1996; Zucker et al., 1998a, b), scientists affiliated with university biotech centers that have ties to a large centers program engage in "less formal" interactions with industry that are not necessarily conducive to discrete outputs but rather to knowledge transfer (Ponomariov and Boardman, 2007). These findings constitute a modest but informative step towards understanding the roles of university researchers and university research centers in the biotech industry. The step is modest because the data do not account explicitly for individual-level incentives to interact with industry. The step is informative because the current study describes the informal processes of university–industry interaction related to biotech, with heretofore unseen detail regarding interactions that do not result in economic or bibliometric outputs.

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