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Disentangling effort and performance: a renewed look at gender differences in commercializing medical school research

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Abstract Recently, questions about gender gaps in science have extended to academic technology transfer. Using systematic data on US medical school faculty, we capture both behavior and performance, examining the hypothesis that women are less likely than men to commercialize their research findings. We pooled faculty invention data from ten departments in three Academic Health Centers from 1991 to 1998—a period when patenting had become prevalent and other researchers note that a gender gap was pronounced. Rather than focusing on patenting, we capture the first step in the commercialization process, as well as the subsequent successful licensing of faculty inventions to a company. We find no significant gender differences in the likelihood of reporting inventions or successfully commercializing them. We do find differences in the number of inventions reported, however, with women disclosing fewer inventions than their male counterparts. Our results demonstrate that gender effects are highly conditioned by employment context and resources. We attribute differences in our findings with regards to gender to the use of outcome measures that capture both behavior and performance, and the inclusion of a more extensive set of control variables.

Keywords University technology transfer · Academic entrepreneurship, university performance metrics · Gender · Biomedicine · Life sciences · Biomedical innovation

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In recent decades, biomedicine has undergone a profound transformation: the propensity to disclose, patent, and license inventions by life science faculty has expanded dramatically as institutions increasingly direct attention to commercial performance (Azoulay et al. 2007). Some worry that this change is reinforcing a gender gap in academic productivity and career attainment because those already successful in the academy are better able to parlay their resources into commercial success (Smith-Doerr 2004; Owen-Smith 2003; Whittington and Smith-Doerr 2005, 2008; Haeussler and Colyvas 2011; Whittington 2011).

Much is made of this assertion that women are less engaged in formal technology transfer—the movement of academic discoveries to industry through patents and licenses for commercial development (Ding et al. 2006). There are, however, reasons to question this gender claim. First, the evidence for this claim is based largely on institution-specific interviews or simple demographic characteristics: females are less likely to patent than men and do so at lower rates (Stephan et al. 2007). Studies based on patent data, however, can be misleading as these data are skewed by administrative, financial, and technical considerations outside inventors' control (Sampat 2006; Nelson 2009). Technology transfer begins when faculty disclose a research finding or invention with commercial potential to the university's technology licensing office (Bercovitz and Feldman 2008). The invention may then move forward to patenting, a step that often depends on a company's expressed interest in licensing the invention. Revenue is realized when the license is signed and reaches different milestones, signaling commercial success. Differences among faculty can occur at each step in this process. As a metric of commercial productivity, patenting does not capture the important distinction between effort and success in making critical linkages to companies (Colyvas and Powell 2009).

Second, some previous research has demonstrated that gender differences disappear once personal and resource characteristics are included in the analysis (Xie and Shauman 2003). Women may have differential access to the key predictors of productivity, such as secure faculty positions at more prestigious universities or greater pecuniary support to enhance research efforts (Fox 2001; Fox and Colatrella 2006). Systematic data that include such variables are rare and difficult to collect, particularly data that account for both behavior and performance, that is, the behavior to file invention disclosures and subsequent performance in terms of licenses to firms.

We enter this discussion with an analysis of cross-sectional faculty data from three prominent US university medical schools from 1991 through 1998. We follow faculty disclosure activity during this period, tracking the subsequent success of these inventions through 2002. Motivated by prior studies and research on organizational behavior, we include individual and institutional characteristics associated with experience and career attainment, occupational setting, resources, and scientific productivity (Thursby and Thursby 2005; Ding et al. 2006; Bercovitz and Feldman 2008; Haeussler and Colyvas 2011). This approach allows us to take advantage of the availability of more detailed data and provides a more conservative test over a time period when other studies found a significant gender difference. By distinguishing between efforts to disclose inventions and the outcome of successfully transferring inventions to firms, our results better clarify claims about gender differences and raise questions about hypothesized variation in womens' technology transfer participation.

1 Academic entrepreneurship and the organizational structure of science

For decades scholarship has emphasized structural and organizational distinctions between industry and the academy, perhaps less for the material features of the science that each is inclined to pursue but rather more for the goals accepted as legitimate, features of the reward system, and norms pertaining to the disclosure of knowledge (Rosenberg and Nelson 1994; Dasgupta and David 1994). From this perspective, academia's emphasis on priority of discovery, rewards of research funds and disclosure through publications reflects a sharp, often contradictory, contrast to industry's focus on market share, profit and proprietary modes of knowledge disclosure (Rhoten and Powell 2007). University and public policy initiatives seeking to combine commercial efforts with academic knowledge production date back to WWII and intensified beginning in the 1980s (Mowery et al. 2004). Along with technological and industrial changes in biomedicine, scholars emphasize the development of a new hybrid regime, especially in the life sciences, that integrates features of both public (university) and proprietary (industry) science (Owen-Smith 2003; Rhoten and Powell 2007; Vallas and Kleinman 2008).

Empirical work from economics to organizational sociology to social studies of science emphasizes that the proclivity of academics to commercialize research findings is conditioned by their position in the career and reward structure of academic science (Shane 2000; Stephan et al. 2007). More established and productive faculty are better positioned to reap the benefits of commercial opportunities and are therefore more likely to engage in technology transfer (Stuart and Ding 2006; Bercovitz and Feldman 2008). For inventors, successful technology transfer requires time, effort, and substantial learning that differs from that needed for academic science (Packer and Webster 1996). Therefore, having more professional experience, the security of tenure, and a stock of scientific and pecuniary resources better situates scientists to mobilize their material and social capital for commercial gain (Stephan and Levin 1992; Casper and Murray 2005; Grandi and Grimaldi 2005; Stuart and Ding 2006).

Numerous mechanisms account for persistent gender differences observed in the biomedical sciences and likely play out across an individual's life course (Xie and Shauman 2003). Scholars argue that women have less access to social and organizational resources and fewer senior-level advisory positions (Bird 2011). Furthermore, academia's opportunity structure excludes women in the early professional development stages, which has long-term ramifications on their careers (Smith-Doerr 2004; Murray and Graham 2007). Whereas much gender research has analyzed stages in the career trajectory where women step out of science (Xie and Shauman 2003), we must also disentangle the steps in the commercialization process by which any gender disparities first present themselves.

Are women less likely than men to take the first step in disclosing inventions and do they do so at lower rates? Or are any gender differences more associated with the transfer to firms? The former suggests that gender differences might follow similar patterns to those of more traditional metrics of scientific productivity, such as grants and publications. The latter raises the question of vulnerabilities at different steps in the commercialization process.

2 Data collection

We utilize primary (archival) and secondary sources, obtained from the institutions and individuals in our sample and accessed through publically available materials. We employ

Table 1 Distribution of faculty members with disclosures among sampled departments from three university medical schools

	Faculty members with disclosures	Faculty members	% Faculty with disclosures
Anesthesiology	31	149	20.81
Cell biology	24	69	34.78
Genetics	25	36	69.44
Immunology	35	47	74.47
Biochemistry	25	44	56.82
Pathology	54	139	38.85
Pharmacology	37	59	62.71
Radiology	35	115	30.43
Neurology	46	93	49.46
Surgery	77	337	22.85
Total	389	1,088	35.75

three archival sources in order to identify our sample, obtain organizational and individual-level data, verify gender, and document our dependent variables: (1) university bulletins for faculty and rank by department; (2) university and individual websites for faculty demographic and biographical information; and (3) university technology transfer offices for invention disclosures and licenses. The secondary data comprised the US National Institutes of Health (NIH)[1] Research Portfolio Online Reporting Tools (RePORT) resource; the US National Library of Medicine (NLM) PubMed database covering Medline and life science journals; the Association of American Medical Colleges (AAMC) faculty roster, the UMI INFORMS dissertation database, and the US Patent and Trademark Office (USPTO) patent database—all containing information back to 1991. We identified faculty from ten medical school departments across three private universities (Table 1) of comparable academic quality. To limit selection concerns, we analyze faculty employed consistently from 1991 through 1998, a sample comprising 1,088 individuals. We matched faculty names to university technology transfer data, identifying both invention disclosures and resultant licenses for each disclosure. We hand-verified each match, utilizing full names, department affiliations, and date of disclosure.

Our data are distinctive from previous studies using patents to capture commercial efforts or outcomes. Often an invention disclosure may result in more than one patent and multiple licenses, depending on universities' legal and strategic considerations. In contrast, we distinguish commercialization attempts and performance of those efforts by identifying disclosures and determining whether each culminated into a license from the time of the disclosure up to 2002, providing at least a three-year window for commercial transfer.

For demographic data, we utilized university administrative records and web-based biographical information including CVs, university profiles, PubMed, UMI INFORMS, and the AAMC. In many instances, gender was not identifiable through names, in which case we confirmed against the sources above, on-line images, and informants at each university. We extracted graduation year and institution to construct a professional experience variable and searched the USPTO on-line for patent applications within 5 years of graduation to construct a variable for technology transfer experience for graduate institutions. We conducted these queries by hand, utilizing assignee's name, city, and

[1] The NIH is a US government research agency made up of 27 different institutes and centers, including the NLM.

patent application date. We obtained funding data for each individual and their departments through the NIH RePORT database, including research grants, contracts, career awards, and cooperative agreements. For publications we utilized the PubHarvestor tool, (Azoulay et al. 2006) which automates the extraction of publication data from the NLM, and manually compared each individual's publications to those we found on CVs.

3 Statistical analysis

Using regression techniques, we estimate the relationship between individual and organizational attributes and four outcomes related to invention disclosure (behavior) and licensing activity (performance): (1) likelihood of reporting an invention; (2) number of inventions reported; (3) number of inventions licensed; and (4) proportion of inventions converting to licenses.

Table 3, models 1 and 2, examine whether a faculty member reported an invention during our 8 year period, estimated with probit models since the dependent variable is dichotomous. In models 3 and 4, the dependent variable is the number of inventions reported, estimated as Poisson models since the dependent variables are count variables. All estimates are presented as incidence ratios. Coefficients less than 1 indicate a variable's negative effect on the dependent variable; coefficients exceeding 1 indicate a positive effect.

Table 4, models 1 and 2, predict the number of reported disclosures that convert to licenses by the beginning of 2002. To account for possible selection bias, we estimate a two-stage Heckman model using an indicator variable for Ph.D. degree as the selection term (Heckman 1976). The dependent variable in models 3 and 4 is the licensing conversion rate, calculated as the percentage of an individual's total disclosures that convert to a license. As the dependent variable is a fraction bounded by 0 and 1, we estimate a general linear model with robust standard errors (Papke and Wooldridge 1996). This model is run on a subset of the sample, which includes the 389 faculty that reported at least one invention from 1991 to 1998.

4 Results

4.1 Distribution of disclosures

Table 1 compares the number of faculty with disclosures to the total number of faculty by department. From 1991 through 1998, 389 of the 1,088 faculty members (35.8%) reported at least one invention, totaling 1,436 disclosures. We find significant variation in disclosure rates across departments, with disclosure being most common among faculty in Immunology (74.5%), Genetics (69.4%), and Pharmacology (62.7%). In absolute terms, professors from Surgery filed the greatest number of disclosures (216), but, given the large size of these departments, the overall proportion of faculty with disclosures was lowest among faculty in Surgery (22.8%) and Anesthesiology (20.8%).

Table 2 shows the distribution of faculty with and without disclosures according to gender, academic degree, and whether they were NIH grantees. The gender distribution in our sample was approximately 15% female and 85% male, similar to the national distribution among medical school faculty, with no significant differences across universities (Magrane et al. 2004). Almost 40% of faculty received NIH support, with a significantly

Table 2 Characteristics of faculty members by disclosure status

	No disclosures ($N = 699$) Number (percent)	Disclosure ($N = 389$) Number (percent)	Total Number (percent)
NIH grantee			
Yes	172 (40.0%)	258 (60.0%)	430 (39.5%)
No	527 (80.1%)	131 (19.9%)	658 (60.5%)
Gender			
Female	110 (68.3%)	51 (31.7%)	161 (14.8%)
Male	589 (63.5%)	338 (36.5%)	927 (85.2%)
Degree			
M.D.	498 (70.14%)	212 (29.86%)	710 (65.3%)
Ph.D.	204 (47.7%)	224 (52.3%)	428 (39.3%)
M.D.–Ph.D.	33 (37.50%)	55 (62.5%)	88 (8.1%)
Other	30 (76.9%)	9 (23.1%)	39 (3.6%)

higher share among those with disclosures ($\chi^2 = 181.96$, $p < 0.0001$). The majority of our sample had either M.D. (65.3%) or Ph.D. degrees (39.3%). Consistent with other studies, we find that reporting inventions is a rare event, with a median number of disclosures of 0, a mean of 1.32, and a maximum number of 30. During the observation period, 389 professors disclosed at least once (35.8%). The likelihood of reporting an invention was higher for NIH grantees, men, and Ph.D. graduates.

4.2 Gender differences and disclosures

Table 3 shows multivariate regressions predicting disclosure activity, estimating two nested models for both dependent variables. Models 1 and 3 relate the dependent variable to gender, faculty, and organization-level characteristics that capture the effects of prior training and experience as motivated by previous studies. These characteristics include experience since the last academic degree, type of degree, whether it is a US degree, and the patenting volume at one's graduate institution. We also incorporated department-level controls for current work setting, including total NIH funding received and an indicator variable for the type of department. Models 2 and 4 add individual occupation, productivity, and resource variables: academic rank, number of publications, and amount of NIH funding per professor.

Across all four models, career experience has a negative effect on disclosure activity; the estimated coefficients are less than one. The coefficients on this variable in model 1 and model 3 indicate that each additional year since graduation reduced the odds of having a disclosure and decreased the expected count of disclosures by 12%. Moreover, the probability of having disclosed was significantly higher for Ph.D. graduates. When all other variables are held constant at their mean values, Ph.D.'s were twice as likely to report an invention. Graduate institution patenting is not related to disclosure activity, but the department's level of NIH support is a significant predictor of both propensity and rate of disclosure. Each additional million dollars in NIH funding was associated with a 5.6% increase in the likelihood of disclosing and a 5.5% increase in the expected number of disclosures.

Consistent with previous claims, model 1 shows that women are 35% less likely to have disclosed an invention; model 3, suggests being female decreases the expected count of disclosures by 47%. The negative effect on likelihood of disclosing is misleading as

Table 3 Logit and Poisson regression models of disclosure activity on scientist and department-level characteristics, 1991–1998

	Invention report participation		Number of invention reports	
	Model 1	Model 2	Model 3	Model 4
Academic work experience	0.980* (−2.26)	0.968** (−2.68)	0.983*** (−4.99)	0.967*** (−7.39)
Graduate institution patenting	1.007 (0.99)	1.013+ (1.82)	1.003 (1.33)	1.005* (1.99)
Non-US degree	1.138 (0.61)	1.534* (2.00)	0.912 (−1.04)	1.190+ (1.94)
PhD degree	2.130*** (4.58)	2.191*** (4.32)	1.107 (1.57)	1.297*** (4.07)
University A	2.252*** (3.33)	1.838* (2.45)	1.509*** (4.93)	1.227* (2.42)
University C	2.039*** (4.51)	1.814*** (3.53)	1.295*** (4.30)	1.017 (0.27)
Female	0.644* (−2.16)	0.791 (−1.11)	0.528*** (−7.10)	0.657*** (−4.60)
Department NIH awards (million USD)	1.056** (2.80)	1.048* (2.24)	1.055*** (7.09)	1.040*** (5.14)
Full professor		1.109 (0.47)		0.957 (−0.59)
Assistant professor		0.850 (−0.84)		0.626*** (−5.95)
Individual NIH awards (million USD)		1.270* (2.41)		1.061*** (7.37)
Number of publications		1.028*** (4.42)		1.018*** (22.14)
Observations	1,088	1,088	1,088	1,088

Estimates of the odds ratios were obtained from probit regression models (models 1 and 2), and estimates of the relative risk were obtained from Poisson regression models (models 3 and 4). All models include indicator variables for department affiliation. *t* statistics in parentheses: $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

significance disappears once key individual-level controls are added. After including rank, publishing activity, and individual-level NIH funding (model 2), gender has no significant effect on the likelihood of disclosing. Academic rank was not related to the propensity to disclose; number of publications and NIH funding had a significant positive effect. Once we control for individual-level occupational and resource factors, women are just as likely to participate in commercializing their research findings as their male counterparts. Model 4 shows, however, that gender remains a significant predictor of disclosure volume, even after controlling for rank, publishing, and funding.

4.3 Gender differences and licensing

Do these gender findings extend to the performance of commercial efforts? Table 4 reports the results of the multivariate regressions predicting licensing activity, run on the subset of 389 faculty reporting at least one invention from 1991 through 1998. The dependent variable in models 1 and 2 is the count of disclosures that convert to licenses, while in models 3 and 4, it is the percentage of individuals' total disclosures that convert to licenses. Model 1 suggests that women are less likely to produce disclosures that become licenses. However, after controlling for academic rank, publishing, and NIH funding, there is no statistically significant gender difference in the number of disclosures licensed. Models 3 and 4 show no statistically significant difference in the rate at which women's discoveries are licensed. Individual NIH funding, degree background, and departmental affiliation were significant predictors of licensing activity.

Table 4 OLS Heckman selection regression and GLM regression models of disclosure activity on scientist and department-level characteristics, 1991–1998

	Number of inventions that convert to licenses		Rate of conversion of disclosures to licenses	
	Model 1	Model 2	Model 3	Model 4
Academic work experience	−0.00783 (−0.42)	−0.00584 (−0.29)	−0.00818 (−0.64)	−0.0163 (−1.10)
Graduate institution patenting	0.00195 (0.15)	0.00435 (0.35)	−0.0128 (−1.45)	−0.0115 (−1.28)
Non-US degree	−0.638 (−1.49)	−0.267 (−0.66)	−0.432 (−1.40)	−0.368 (−1.17)
PhD degree			0.615** (3.04)	0.622** (3.08)
University A	0.750+ (1.65)	0.725+ (1.68)	1.373*** (4.62)	1.435*** (4.53)
University C	1.078*** (3.51)	1.212*** (4.17)	1.434*** (6.56)	1.472*** (6.43)
Female	−0.970* (−2.36)	−0.636 (−1.64)	−0.339 (−1.12)	−0.262 (−0.87)
Department NIH awards (million USD)	0.0395 (1.05)	0.0355 (1.01)	−0.0244 (−0.98)	−0.0254 (−1.00)
Full professor		−0.627+ (−1.70)		0.128 (0.53)
Assistant professor		−0.0994 (−0.27)		0.170 (0.67)
Individual NIH awards (million USD)		−0.0204 (−0.41)		0.0728** (2.69)
Number of publications		0.0429*** (7.48)		0.00216 (0.61)
Constant	0.333 (0.35)	−0.284 (−0.31)	−1.353** (−2.71)	−1.467** (−2.58)
Selection equation				
Ph.D. degree	0.733*** (9.10)	0.733*** (9.10)		
Constant	−0.674*** (−12.72)	−0.674*** (−12.72)		
Mills lambda	−0.212 (−0.36)	−0.596 (−1.07)		
Observations	1,088	1,088	389	389

Coefficient estimates were obtained from Heckman corrected OLS regression models (models 1 and 2) and from GLM regression models (models 3 and 4). All models include indicator variables for department affiliation. t statistics in parentheses: $^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

5 Discussion

The growing interest among academic faculty in commercial activity provides new challenges and opportunities. As such, technology transfer data have increasingly become metrics for productivity and a focus for ongoing debates about gender gaps in science. Both research and policy can better direct attention to the loci of these differences through more detailed data collection and analysis within departments and institutions.

Our results suggest that much of what is attributed to gender reflects occupational and resource factors, reflecting the volume of engagement, rather than discrete proclivity to commercialize or the level of success in doing so (Fox and Colatrella 2006; Whittington 2011). Furthermore, and particularly important for policy and management, women's inventions in our sample were just as likely as men's to secure licenses to firms. Combined with our finding of similar likelihood but lesser rate of disclosing, women, and arguably other underrepresented groups, might well be an untapped source of entrepreneurial talent within academia. For decades research in organizational behavior has underscored this point within firms (Kantor 1977, 1993).

Why are our findings different from much of the commercialization literature? We emphasize that our results are consistent with research using other measures of productivity, such as publications, where gender differences in the life sciences are negligible if not non-existent once appropriate controls are in place (Xie and Shauman 2003). Our results also follow a legacy of work that cautions against the use of patent data as an empirical measure of innovation, entrepreneurship, and productivity (Jaffe and Trajtenberg 2002; Jaffe and Lerner 2004; Nelson 2009).

Also, our data are more precise in capturing commercial engagement, as well as individual and organizational attributes, especially inclusive of departments, in ways that few other studies have been able to incorporate in the same analysis. We utilize invention disclosures, which reflect the first step in the commercialization process, and licenses, which estimate transfer to firms. We can thus compare the behavior of engaging in commercializing to outcomes of that engagement and circumvent measurement problems with patents.

Our selection of this retrospective time period, although based on availability of data, allows us to examine differences that have been shown to exist at a substantial level. Had we more recent data, one might have deduced from our findings that we show a narrowing gender gap. On the contrary, we claim that understanding gender differences in technology transfer requires appropriate controls and empirical measures that distinguish behavior from performance.

Our data, however, have important limitations that influence the methods we can employ and the generalizeability of results. First, our sample limits our ability to reliably capture institutional differences, which can be especially important when considering variations in technology transfer experience, management, and access women may have to those resources that influence productivity. Second, faculty entry and exit data would further help address selection effects, and personal characteristics related to marriage and children would provide additional controls that account for gender differences across a range of fields (Whittington 2009, 2011). Third, commercial efforts may be conditioned by teaching loads and forms of research support, such as industrial funds and research assistants. Fourth, our measures, in capturing invention disclosures and their attendant licenses, reflect only one formal form of technology transfer, specifically in the life sciences. We caution that the evidence is mixed with respect to other disciplines (such as the engineering, computer, and physical sciences) and less formal means of technology transfer (such as consulting and co-authorship with industry personnel)—data that were unavailable for our sample (Link et al. 2007; Whittington 2009; Ridgeway 2009; Haeussler and Colyvas 2011).

For scholarship and practice, understanding faculty women's engagement in entrepreneurship is a strategic setting, providing a window into new "fault lines" in academic science (Stuart and Ding 2006; Vallas et al. forthcoming). Policymakers face a puzzle in this regard (Haeussler and Colyvas 2011). On the one hand, much scholarship emphasizes ways in which entrepreneurial opportunities in the academy reproduce stratification orderings in science, advantaging those with status and resources because they are better poised to engage in the dual objective of scientific advance and commercial development (Whittington 2011). Yet the premise behind many local and government policies is that entrepreneurial opportunities enable scientists to circumvent existing academic barriers since law and commercial markets are less sensitive to the rigid criteria of the academy (Powell et al. 2007; Rhoten and Powell 2007). Obtaining property rights over one's research relies on legal definitions of non-obviousness, novelty, and use, rather than peer-reviewed assessments of contribution to scientific advance and downstream citations to one's work. Although the balance of entrepreneurship and academic science is highly conditioned by structural and career factors, many levers are largely in the hands of local universities, specific funders, and regulators of science (Fox 2010; Bird 2011).

As technology transfer data increasingly take hold as a benchmark for comparison to other institutions, universities have the opportunity to reflect on the individual, resource, and occupational characteristics that are most closely associated with their own performance. Our hope is that future data collection efforts by researchers and the institutions that seek to understand the efficacy of their own policies will address these factors. A strong case can be made that gender differences may vary by institutional and scientific contexts where gender representation is much lower or organizational procedures that moderate any potential biases are weak (Ridgeway 2009).

A necessary first step is for institutions to assess entrepreneurial engagement in a more meaningful way. Most technology transfer programs track counts of activities, such as number of patents, licenses, and revenues received, often grouped by departments and schools, with no multivariate associations that take these career and resource factors into account (Colyvas and Powell 2009). Second, institutions can manage their research, training, and commercial outreach data in a more relational, longitudinal, and comprehensive way that enables examination of these important predictors of entrepreneurship. Despite a long legacy of institutional research, most universities have remained largely decentralized in their internal data collection and use with respect to faculty outputs. As a result, universities have demonstrated a remarkable reliance on public benchmarks and rankings from professional and private associations, despite infrastructure and routines already in place that collect more meaningful data from an organizational learning standpoint (Colyvas 2011).

Some universities have made recent advances, such as implementing technologies that capture their institution's funding, publication, and co-authorship data. An important next step would be to create internal linkages to personnel and commercialization data that connect individual, departmental, and school attributes at the time of each invention. With such data, institutions can support the replication of multivariate studies, which would help to inform strategies for seeding entrepreneurship.

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