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Not in the Job Description: The Commercial Activities of Academic Scientists and Engineers

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Abstract. Scholarly work seeking to understand academics' commercial activities often draws on abstract notions of the academic reward system and the representative scientist. Few scholars have examined whether and how scientists' motives to engage in commercial activities differ across fields. Similarly, efforts to understand academics' choices have focused on three self-interested motives—recognition, challenge, and money—ignoring the potential role of the desire to have an impact on others. Using panel data for a national sample of over 2,000 academics employed at U.S. institutions, we examine how the four motives are related to commercial activity measured by patenting. We find that all four motives are correlated with patenting, but these relationships differ systematically between the life sciences, physical sciences, and engineering. These field differences are consistent with differences across fields in the rewards from commercial activities as well as in the degree of overlap between traditional and commercializable research, which affects the opportunity costs of time spent away from "traditional" academic work. We discuss potential implications for policy makers, administrators, and managers as well as for future research on the scientific enterprise.

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1. Introduction

A large literature has examined academics' engagement in commercially oriented research and related activities. An important driver of this work are concerns that deepening ties with commerce may lead scientists to neglect academia's core mission of "pure" research or compromise access to research findings (Dasgupta and David 1994). Even though most of the evidence does not support these concerns (Agrawal and Henderson 2002, Breschi et al. 2008, Fabrizio and Minin 2008, Azoulay et al. 2009, Buenstorf 2009, Goldfarb et al. 2009, Thursby and Thursby 2011, Perkmann et al. 2013), they remain salient in both the scholarly literature and public discourse. On the other side of the ledger, there has been a hope, particularly among policy makers, that deepening commercial ties may increase the regional and national economic impact of academic knowledge. These hopes are reflected in a range of policies designed to encourage such interactions, most notably the Bayh–Dole Amendment (Mowery et al. 2001).

Whether the goal is to stimulate commercial engagement or discourage it, it is useful to understand why academics engage in commercially applicable research. Guided by a conceptual framework, this paper examines the empirical relationships between academics' motives (i.e., desires for payoffs, such as career advancement and money) and their commercial activities.[1] By highlighting individual differences in academics' motives as well as field differences in reward structures, our work also extends the seminal argument of Merton (1973). Postulating a universal set of values and norms, the perspective of Merton (1973) has framed much of the prior literature on the scientific enterprise generally and academics' commercial engagement in particular.

Although there is a growing body of research on the motives and incentives of academics who engage in commercial activities (Owen-Smith and Powell 2001, Thursby et al. 2001, Bercovitz and Feldman 2008, Fini and Lacetera 2010, Lam 2011, Hvide and Jones 2018), two important gaps remain. First, efforts to understand academics' commercial activities often rely on notions of a representative academic or have examined particular fields in isolation. Yet, the benefits and costs of commercial activities and, thus, academics' motives tied to such activities are likely to differ systematically across fields. Studying such differences is important given that there are significant field differences in the *level* of academics' commercial engagement (Cohen et al. 2002, Lim 2004, D'Este and Perkmann 2011) and given field differences in the nature of research (Layton 1976, Fleming and Sorenson 2004, Sauermann and Stephan 2013, Nelson 2016).

Second, much of the work on academics' motives around commercial engagement assumes that departures from goals of peer recognition and career advancement (Merton 1973) are tied to other self-interested motives—not only money but also intrinsic rewards (Stephan and Levin 1992, Dasgupta and David 1994, Lam 2011). Notably absent is the motive of social impact. This is surprising not only given the salience of this motive in historical and qualitative accounts (Stokes 1997, Shapin 2008) but also because social benefits have been invoked to justify the public funding of academic research as well as policy efforts that promote academic entrepreneurship (Bush 1945, Salter and Martin 2001, Lane and Bertuzzi 2011). Moreover, employees' social motives have been shown to have important impacts in other organizational settings (Fehr and Fischbacher 2002, Grant 2007, Bode and Singh 2018).

To address these gaps, we first briefly outline our conceptual framework, which is formalized in the online appendix. We then use that framework to examine and interpret cross-field differences in the motives tied to commercial activity observed in a sample of over 2,000 life scientists, physical scientists, and engineers working in over 100 U.S. academic institutions.

2. Conceptual Framework

We assume that those who have selected into research-oriented academic careers wish to advance those careers and that the standard path for career advancement is achieving some degree of eminence via traditional academic research (Merton 1973, Stern 2004, Roach and Sauermann 2010). We also assume that academics who allocate effort to commercial activity incur opportunity costs owing to the loss of time dedicated to traditional academic research and the associated career benefits. This loss can, however, be offset by the rewards from commercially applicable research and related activity. Expanding on much of the prior literature, a first important feature of our framework is that these rewards may include not only the prospect of greater income but also the prospect for social impact.

A second important feature of this framework is that the loss of time dedicated to traditional academic research as well as the rewards tied to commercial activity may differ across fields. In particular, to the extent that traditional research in a field is closer to market applications, commercially applicable work will detract less from work that supports an academic career. For example, in the basic physical sciences, where traditional research advances understanding of natural phenomena, research results are typically far removed from commercial interest. Thus, effort spent on commercial research will tend to detract from academic research and its rewards (Toole and Czarnitzki 2010). By way of contrast, in engineering and the applied sciences (henceforth referred to as engineering), a good deal of traditional academic research focuses on solving concrete problems and creating useful artifacts (Layton 1976, Allen 1977, Vincenti 1990, Dym et al. 2005). Thus, generating commercializable outcomes requires less departure from traditional work in these fields (Goldfarb et al. 2009, Crespi et al. 2011). Moreover, we argue that, in fields with a high degree of overlap between traditional work and commercial activity, commercial activity may not only yield rewards, such as money or social impact, but also contribute to academic advancement, further lowering the opportunity costs of doing commercial work. Supporting this idea, there is evidence that patenting can increase academics' reputation among peers (Audretsch et al. 2010, Haeussler and Colyvas 2011) and, in some instances, prospects for academic promotion (Lipka 2006, Azoulay et al. 2007, Butkus 2007).[2]

Assuming that academics differ in their preferences for the different types of rewards, this logic offers implications regarding the motives that we expect to characterize those academics who do commercially relevant work in a given field and how such motives may differ across fields. In fields where opportunity costs of pursuing commercially relevant work are greater, the academics who choose to do such work are likely those who place a lower value than others on academic advancement and a higher value on rewards such as money or social impact. In fields where traditional research is closer to market applications, however, the motives of academics who pursue more commercially relevant research may not differ much from the motives of their colleagues who focus on traditional academic work.

In the following section, we explore the empirical relationships between academics' motives and their commercial activities. In light of data limitations, our analysis does not identify the causal impact of motives. Rather, our contribution is to document correlations between academics' commercial activities and a range of individual motives—including the desire for social impact—that may speak to the interplay of individual motives with field differences in the rewards and opportunity costs of commercial engagement.

3. Data and Measures

3.1. Data Sources

Our empirical analysis is based on two waves of the Survey of Doctorate Recipients (SDR) obtained from the National Science Foundation (NSF) under a restricted use license. The SDR is a longitudinal survey, and its sampling population includes individuals who have obtained a doctoral degree in a science, engineering, or health field from a U.S. institution and lived in the United States at the time of the surveys. In 2001 and 2003, the SDR achieved response rates of approximately 80%.[3] In this paper, we focus on those PhDs who are full-time employees in academia (defined as educational institutions by the NSF) and for whom research is either the most important or second most important work activity. We exclude postdoctoral researchers because they may pursue both academic and nonacademic career paths and tend to have limited control over the allocation of research effort. Our final sample includes 2,094 scientists and engineers at 160 institutions. As discussed below, we distinguish between academics in the life sciences, the physical sciences, and engineering.

We augment the SDR data with data on (1) universities' policies regarding the share of licensing income going to the inventor from Lach and Schankerman (2008) as well as from university websites and inquiries with administrators, (2) the year in which academic institutions started a formal technology transfer office (TTO) from the Association of University Technology Managers surveys as well as from websites and through inquiries to administrators, and (3) PhD program quality from the National Research Council (NRC) (Goldberger et al. 1995) as proxies for the quality of the departments in which respondents were educated and employed.

3.2. Measures

This section describes key dependent and independent variables; Table 1 shows summary statistics for all variables by field.

3.2.1. Commercial Activity. We proxy for academics' commercial activities using U.S. patent application counts (*PATS*). Each respondent self-reported in 2003 the number of patent applications in which he or she was named as an inventor over the 5 years prior to the survey.[4] We also code a dummy variable, *ANYPAT*, which takes on the value of one for academics with at least one patent application. These measures capture all patent applications on which respondents are listed as inventors, not only those going through university TTOs.

We observe significant differences in patenting across fields: Engineers have the highest average count of patent applications followed by life scientists and physical scientists (see also Figure A1 in the online appendix for histograms). These field differences in

Table 1. Summary Statistics

		Life sciences		Physical sciences		Engineering	
Variable	Variable type	Mean	SD	Mean	SD	Mean	SD
PATS (U.S. patent applications)	Count	0.62	3.43	0.55	2.69	1.08	3.19
ANYPAT	Dummy	0.21	0.41	0.16	0.36	0.28	0.45
Imp. advancement	4 point	3.48	0.61	3.40	0.65	3.44	0.64
Imp. income	4 point	3.36	0.55	3.29	0.59	3.38	0.53
Imp. challenge	4 point	3.87	0.35	3.91	0.29	3.89	0.32
Imp. contrib. society	4 point	3.57	0.57	3.44	0.62	3.59	0.57
Carnegie I	Dummy	0.44	0.50	0.70	0.46	0.66	0.47
Carnegie II	Dummy	0.09	0.28	0.09	0.28	0.14	0.34
Doctorate granting	Dummy	0.04	0.19	0.13	0.33	0.12	0.32
Medical school	Dummy	0.44	0.50	0.08	0.27	0.08	0.27
Private university	Dummy	0.27	0.44	0.28	0.45	0.26	0.44
Department NRC score	Continuous	3.25	0.81	3.24	0.90	3.05	0.85
PhD NRC score	Continuous	3.50	0.66	3.72	0.74	3.53	0.76
TTO age	Continuous	20.02	11.98	19.19	13.04	19.75	14.29
Royalty share	Continuous	0.42	0.10	0.42	0.11	0.41	0.10
Not tenure track	Dummy	0.35	0.48	0.28	0.45	0.12	0.33
Male	Dummy	0.69	0.46	0.84	0.37	0.84	0.36
Age	Continuous	47.99	9.09	48.56	10.47	46.06	9.45
White	Dummy	0.75	0.43	0.78	0.41	0.63	0.48
Asian	Dummy	0.16	0.36	0.13	0.34	0.21	0.41
Other race	Dummy	0.09	0.29	0.09	0.28	0.15	0.36
U.S. citizen	Dummy	0.93	0.26	0.90	0.30	0.89	0.31
Exposure	Continuous	4.94	0.30	4.94	0.28	4.91	0.34
ln *publications*	Continuous	2.35	0.86	2.41	0.95	2.19	0.86

levels of commercial activity are consistent with differences in the costs of engaging in commercial activity noted above, though they may also reflect differences in the associated rewards.

3.2.2. Motives. In 2001, respondents were asked, "When thinking about a job, how important is each of the following factors to you..." Respondents rated the importance of each factor on a four-point scale anchored by one (very important) and four (not important at all); for ease of interpretation, we reverse coded these items such that higher scores indicate higher importance. We feature four factors and associated motives: opportunities for advancement, salary, intellectual challenge, and contribution to society. These measures capture respondents' general preferences for different kinds of work-related payoffs (see also Sauermann and Cohen 2010, Agarwal and Ohyama 2013). In this analysis, we use the desire for salary to represent the desire for financial income more generally.[5] Although the average importance ratings for all four job attributes are generally high, the correlations between them, ranging from −0.06 (income and challenge in engineering) to 0.36 (advancement and income in the physical sciences), are not, suggesting that the measures capture distinct constructs (Table A1 in the online appendix).

The means of motives are similar across fields. Indeed, we find no statistically significant differences in the importance of income, intellectual challenge, or advancement reported by life scientists, physical scientists, and engineers. Motives related to social impact, however, are slightly higher among life scientists and engineers than among physical scientists. Although levels of motives must be interpreted with caution given potential response biases (see the online appendix), the observed differences in social impact motives across fields are consistent with sorting of individuals into fields as well as with ex post socialization effects (see Azoulay et al. 2017, Sauermann 2018).

3.2.3. Academic Field. As noted, we distinguish between respondents who received their PhD in the life sciences (n = 1,037), physical sciences (n = 585), and engineering and the applied sciences (n = 472). In the regression analyses, we also control for fields at a more detailed level (biochemistry, cell and molecular biology, microbiology, food sciences, environmental and health sciences, and other biological sciences; physics, chemistry, earth sciences, and mathematics; and computer science, chemical engineering, electrical engineering, mechanical engineering, civil and industrial engineering, and other engineering, respectively).

Table A2 in the online appendix describes control variables, such as type of academic institution, age of the university's TTO, the share of patent royalty income going to the inventor, quality of PhD training and current department, and publication productivity, as well as a range of demographic characteristics.

4. Empirical Specification

Our featured dependent variable is the number of patent applications in the prior five years. To address the count nature of this variable, we estimate Quasi-Maximum Likelihood (QML) Poisson regression models (Silva and Tenreyro 2006). The following is our benchmark specification:

$$E[PATS_i|\boldsymbol{MOTIVES_i}, \boldsymbol{X}] = \exp\Big(\boldsymbol{\beta_0} + \boldsymbol{\beta_1'}\boldsymbol{MOTIVES_i} + \boldsymbol{\beta_2'}X\Big),$$

where $PATS_i$ is respondent i's patent application count over the 1998–2003 time period (as reported in 2003); $\boldsymbol{MOTIVES_i}$ is a vector of motives measured in 2001, reflecting preferences for career advancement, income, intellectual challenge, and social impact; and $\boldsymbol{X}$ is a vector of control variables taken from the 2001 survey and other data sources. Regressions of $PATS$ provide insights into the intensive margin of patenting (i.e., the number of patent applications); we also estimate similar regressions using $ANYPAT$ (indicating whether a respondent had any patent applications at all) to gain insights into the extensive margin. These regressions are estimated using linear probability models. Standard errors for all regressions are clustered at the level of the university.

Because our framework suggests different effects of motives on academics' commercial effort across fields, we estimate our regressions separately for researchers in the life sciences, physical sciences, and engineering, and we compare the resulting coefficients. This approach also implies that the coefficients that we estimate reflect heterogeneity across individuals *within* fields (e.g., some scientists in a particular field care more about a particular motive, and those individuals also patent more) rather than differences in motives across fields (e.g., all scientists in a particular field care more about a particular motive and also patent more).

5. Results

Table 2 documents the relationships between academics' motives and their patenting activities. We begin by briefly reporting the basic results and then interpret the results, focusing on cross-field differences.

In the life sciences (Table 2, Model (1)), we find a statistically significant positive relationship between

Table 2. Main Regression Results

	Life sciences	Physical sciences	Engineering	Life sciences	Physical sciences	Engineering
	(1)	(2)	(3)	(4)	(5)	(6)
Variable	*PATS*	*PATS*	*PATS*	*ANYPAT*	*ANYPAT*	*ANYPAT*
Imp. advancement	0.395	−0.616**	0.475*	0.013	−0.021	0.068*
	[0.272]	[0.220]	[0.211]	[0.022]	[0.030]	[0.030]
Imp. income	−0.047	0.398	−0.375$^+$	0.005	0.063$^+$	0.012
	[0.171]	[0.341]	[0.203]	[0.023]	[0.033]	[0.037]
Imp. challenge	−0.149	−0.307	1.633*	0.007	0.002	0.196**
	[0.371]	[0.301]	[0.730]	[0.032]	[0.049]	[0.049]
Imp. contrib. society	0.826**	−0.084	−0.079	0.082**	0.043*	−0.013
	[0.203]	[0.207]	[0.230]	[0.021]	[0.021]	[0.041]
Carnegie II	0.721	−0.184	−0.236	0.092	0.019	−0.062
	[0.373]	[0.412]	[0.499]	[0.065]	[0.068]	[0.056]
Doctorate granting	−0.010	−0.198	−0.998**	0.037	0.027	−0.032
	[0.385]	[0.529]	[0.364]	[0.058]	[0.059]	[0.058]
Medical school	0.813*	1.006**	0.082	0.077**	0.041	0.031
	[0.339]	[0.360]	[0.369]	[0.029]	[0.074]	[0.088]
Private university	−0.397	0.076	0.432	−0.020	0.018	0.014
	[0.295]	[0.273]	[0.313]	[0.033]	[0.042]	[0.045]
TTO age	0.002	−0.006	−0.011	0.001	−0.001	−0.001
	[0.006]	[0.009]	[0.008]	[0.001]	[0.001]	[0.001]
Royalty share	1.167	−3.101$^+$	−0.184	−0.244$^+$	−0.061	−0.069
	[1.546]	[1.594]	[0.979]	[0.147]	[0.181]	[0.206]
Not tenure track	−0.561	0.555	−0.437	−0.083**	0.017	−0.042
	[0.353]	[0.419]	[0.455]	[0.031]	[0.044]	[0.070]
Dept. NRC score	0.803**	−0.042	−0.006	0.042*	0.002	0.038
	[0.276]	[0.179]	[0.157]	[0.020]	[0.023]	[0.029]
PhD NRC score	0.144	0.124	0.377*	0.002	−0.006	0.026
	[0.181]	[0.199]	[0.162]	[0.022]	[0.021]	[0.029]
Male	0.570$^+$	0.557	0.693$^+$	0.020	−0.023	0.085
	[0.316]	[0.358]	[0.358]	[0.027]	[0.038]	[0.053]
U.S. citizen	0.355	0.976$^+$	0.604	0.051	−0.028	0.168**
	[0.380]	[0.552]	[0.468]	[0.048]	[0.053]	[0.056]
Age cat. fixed effects	Included	Included	Included	Included	Included	Included
Race fixed effects	Included	Included	Included	Included	Included	Included
Subfield fixed effects	Included	Included	Included	Included	Included	Included
Exposure	Included	Included	Included	Included	Included	Included
Constant	−11.558**	−0.913	−10.519**	−0.369	−0.052	−1.189**
	[2.966]	[1.960]	[3.123]	[0.261]	[0.336]	[0.453]
Observations	1,037	585	472	1,037	585	472
Log pseudolikelihood	−1,364	−561.9	−812			
R^2				0.090	0.160	0.144

Notes. Omitted category is Carnegie I institution. Columns (1)–(3) present estimates from QML Poisson specifications. The dependent variable *PATS* is the number of patent applications for each scientist. Exponentiating the coefficients, subtracting 1, and multiplying by 100 yield the percentage change in patent application counts for a one-unit change in the independent variable. Columns (4)–(6) present estimates from linear probability models. The dependent variable *ANYPAT* takes on the value of one if the scientist applied for at least one patent and zero otherwise. Coefficients indicate the change in the probability of applying for at least one patent for a one-unit change in the independent variable. Robust standard errors in brackets are clustered at the level of the university.

$^+p < 0.1$; $^*p < 0.05$; $^{**}p < 0.01$.

patent application counts and the desire for social impact. Researchers with a one-standard deviation (SD) higher motive to contribute to society have a 59.8% higher expected patent count. Income, challenge, and career advancement motives have no significant relationship with patenting. In the physical sciences (Table 2, Model (2)), the advancement motive has a statistically significant *negative* relationship with patenting; a one-SD higher score is associated with a 33.0% lower patent count. Income, challenge, and social impact motives have no significant relationship with patenting. Among engineers (Table 2, Model (3)), we find a strong positive coefficient on the challenge motive as well as the career advancement motive. One-SD higher scores on the two motives are associated with 68.3% and 35.6% higher expected patent counts, respectively. Motives related to income or social impact have no significant coefficients. Formal tests confirm that the differences in the coefficients of motives across fields are statistically significant.[6]

Models (4)–(6) in Table 2 show the results for the *ANYPAT* regressions estimated using linear probability models. In the life sciences and engineering, the qualitative patterns for the motive variables are largely the same as for the *PATS* regressions. In the physical sciences, the negative coefficient on advancement motive loses its statistical significance, whereas the positive coefficient on social impact motives becomes statistically significant, and the positive coefficient on income becomes marginally significant.

Our framework suggests that these different relationships between motives and commercial activity across fields may reflect differences in the opportunity costs of commercial engagement as well as in the associated rewards. We now discuss these possibilities in more detail for each of the four motives.

One notable result in Table 2 is the statistically significant, negative relationship between advancement motives and patent counts in the physical sciences (Table 2, Model (2)), suggesting that physical scientists who care strongly about their academic careers allocate less effort to commercial activity. This contrasts sharply with engineering, where advancement motives have a significant positive coefficient in the count and linear probability models. Interpreted in light of our framework, these contrasting results are consistent with the existence of higher opportunity costs of commercial work in the physical sciences than in engineering; physical scientists who engage in commercial activities may give up more "traditional" research as well as the associated career rewards than do engineers. In addition, the observed differences may also reflect that fields differ in the career incentives associated with commercial activities, i.e., that commercial outputs, such as patents, are looked upon more favorably by academic peers in engineering than in the physical sciences (Azoulay et al. 2007, Haeussler and Colyvas 2011).[7] We can only speculate why, in the physical sciences, the negative coefficient of advancement motives is not statistically significant in the *ANYPAT* regression. One conjecture is that physical scientists may still be able to reconcile a small amount of commercial work with maintaining traditional lines of research, limiting detrimental effects on career advancement. Generating higher volumes of commercial output, however, may require a more fundamental shift away from traditional areas of research, especially in a field where the distance between commercial work and traditional research is large.

Perhaps the most notable result is the statistically significant relationship between commercial activity and the social impact motive in the life sciences. A possible explanation is that life scientists who engage in such activity expect significant social benefit, consistent with the notion that the social benefits from commercial activity are especially salient in the life sciences. Our particular measure, patenting, may also reinforce this interpretation. Life scientists are likely aware of the fact that, for society to realize the health benefits from new discoveries, securing patents is essential in order to provide companies the incentive to make the downstream investments typically required to bring new drugs or therapies to market (Cohen et al. 2000, Sampat et al. 2003).[8] Note that we find the strong positive relationship between the importance of social impact and patenting *within* the sample of life scientists; this relationship is thus unlikely to reflect that life scientists typically have a stronger desire to contribute to society and also happen to patent more. Indeed, our interpretation is consistent with the observation that the social impact motive has a statistically significant coefficient in the *ANYPAT* regression also among physical scientists (even though physical scientists rate social impact overall less important than life scientists or engineers) (Table 1). The latter coefficient suggests that perceived social impact may be one of the factors that compensates physical scientists for the opportunity costs of allocating effort to commercial activity.

We had no priors as to whether intrinsic rewards, such as intellectual challenge, are more strongly tied to traditional academic work or to commercial activity. The results suggest that the answer depends on the field. We find no significant association between patenting and challenge motives in the sciences but a statistically significant positive coefficient in engineering. It seems that engineers—in contrast to their colleagues in the sciences—perceive considerable intrinsic benefits from doing commercially relevant work (see Layton 1976). This result may be of broader relevance for our understanding of scientists' motivations: much of the seminal work on intrinsic motivation thinks of this construct in abstract terms and identifies factors that promote (or reduce) intrinsic motivation generally (Hackman and Oldham 1976, Amabile 1996, Frey and Jegen 2001). However, intrinsic rewards are subjectively generated, and tasks that some people find interesting and challenging may not be perceived as such by others. Future research on how scientists perceive intrinsic rewards and what role is played by the broader organizational context or field seems particularly interesting (to us).[9]

Finally, Table 2 shows no systematic relationship between income motives and patenting in any of the three fields.[10] Incidentally, our control for the share of royalty income going to academic inventors also has no significant relationship with patenting. As such, the data show less of an association between commercial activities and financial motives or incentives than might be expected given the prominence of financial payoffs from patenting in the public discussion. One explanation might be that, notwithstanding the very large financial payoffs resulting from a few outlier patents, the expected financial returns from patenting are very low (Lach and Schankerman 2008, Stephan 2012). It may also be that our measure of the importance of salary only partly captures income motives in a more general sense. Additional analyses to probe these results regarding financial motives and incentives leave the main conclusions unchanged (see the online appendix).

The online appendix reports a number of supplementary analyses, including regressions that control for scientific productivity, examine potential changes in motives over time, interact motives with financial incentives (royalty shares), and use university fixed effects to control for other factors that may shape academics' decisions to engage in commercial activity. The observed relationships between motives and commercial activity are consistent with our main analysis.

6. Discussion

Using two waves of survey data on over 2,000 academics at U.S. institutions, we document correlations between individuals' motives and their commercial activity. We find that these relationships differ across broadly defined academic fields. In the life sciences, those academics who most actively engage in commercial activities are characterized by strong preferences for social impact. In the physical sciences, the most active patentees are those who have little concern for career advancement, although social impact motives predict which physical scientists patent at all. In engineering, patenting relates to motives of challenge and advancement. These results highlight the importance of considering heterogeneity in individuals' motives *within* fields as well as differences in the rewards and opportunity costs tied to commercial work *across* fields.

Our results are subject to a number of limitations. First, although we consider a broader set of motives than typically discussed in the economics and sociology of science, there may be additional motives for commercial engagement that are not captured by our measures, including, for example, patenting as a way to ensure freedom to work on certain problems, or commercial activities as a means to acquire resources for research (Owen-Smith and Powell 2001, Murray 2010, Perkmann et al. 2013). Second, we focus on patenting as one of several possible facets of commercial activity. Although patenting is likely complementary to—and correlated with—other commercial activities, such as consulting or new venture creation (Jensen and Thursby 2001, Haeussler and Colyvas 2011), future work is needed to study how individual motives relate to other commercial activities and how such relationships differ across fields. Third, the opportunity costs and rewards from commercial activities may change as "traditional research" in fields evolves, as commercial activities become more accepted among academics, and as universities and policy makers more strongly consider commercial activities as part of "broader impact" efforts (Stokes 1997, Butkus 2007, Bercovitz and Feldman 2008). As such, it would be useful to study how academics' institutional environment is changing and how such changes affect the relationships explored in this paper. Fourth, variables used in the analysis may be subject to measurement error. For example, our measures of motives are quite coarse and may be affected by response biases (see the online appendix for a more detailed discussion). Similarly, patent applications may not fully capture academics' intent to patent because Technology Transfer Offices also play an important role in decisions over whether to file for a patent. Fifth, we do not estimate the causal impact of motives on commercial activity but document associations between measures of motives and patent applications that are likely conditioned by sorting across fields and may be subject to other sources of endogeneity. Nonetheless, the observed correlations are consistent with a view that differences in the rewards and opportunity costs of commercial activity across fields are linked to the motives of academics that pursue such activity within those fields.

The observed correlations between motives and commercial activities as well as the differences across fields suggest potential implications for public and managerial policies. First, a major objective of the Bayh–Dole legislation was to generate social benefits by increasing the use and exploitation of knowledge developed in academia (Sampat et al. 2003). To the extent that academics care not only about private benefits but also about making a difference in society, their objectives may be more aligned with policy objectives than previously thought. Second, the opportunity costs and rewards from commercial activities differ across fields. Thus, policies and management practices that take into account field differences may be more effective than those that apply the same tools in very different contexts. For example, there may be less reason for concern about distractions from traditional work in fields where academic and commercial work are closely aligned (Azoulay et al. 2007, Fabrizio and Minin 2008).

Our findings may also be useful in light of discussions about potential detrimental effects of commercial activities—patenting in particular—on the sharing and diffusion of academic knowledge (Murray and Stern 2007, Perkmann et al. 2013). Intellectual property rights can be used in different ways, and their effects on knowledge flows likely depend on the motives of the inventors and patent holders. A scientist who patents in order to improve social welfare, for example, may be willing to share knowledge more freely than a scientist who patents in order to appropriate financial returns.

Our study also has implications for the broader literature on science and innovation. First, although the Mertonian paradigm has allowed us to understand the distinctive features of science, future research may benefit from considering more explicitly how the norms and incentives of scientists differ across fields or organizational contexts (Crespi et al. 2011, Sauermann and Stephan 2013). Second, although much of the prior literature has focused on the representative scientist characterized by self-interested motives, our results reveal important heterogeneity across scientists as well as the relevance of social motives that have received little attention in prior work. Recognizing these aspects may provide a richer foundation for future work on scientists' decisions such as which career path to take, which employer to work for, or what research problems to tackle (see Besley and Ghatak 2005, Francois 2007, Salter et al. 2017, D'Este et al. 2018). More generally, a broader view of scientists' motives and the consideration of differences in the scientific enterprise across fields has the potential to enrich the study of science and allow us to provide more robust advice to managers, university administrators, and policy makers.

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Endnotes

[1] In line with prior work (Stern 2004, Sauermann and Cohen 2010), we distinguish individual-level *motives* (e.g., the desire for money) from *rewards and incentives* that may be provided by the employer or other actors (e.g., money paid to the owner of a patent). The online appendix provides additional detail on the interplay between motives and incentives.

[2] Commercial activity may also benefit traditional academic research: for example, because it provides additional financial resources or suggests novel ideas for research (Azoulay et al. 2009, Perkmann et al. 2013). In our model, such effects could be captured as commercial activity supporting career advancement (indirectly through research productivity). Notwithstanding this possibility, we assume that individual academics face a fundamental tradeoff between allocating a limited time budget to research versus commercialization and that a unit of the former tends to yield greater career advancement than a unit of the latter.

[3] Details about the SDR are available at http://www.nsf.gov/statistics/srvydoctoratework/.

[4] The SDR data are anonymized and cannot be matched to other data sources, such as patent records.

[5] In our conceptual model, financial payoffs may result from traditional research (e.g., rewards for publications or salary raises indirectly resulting from career advancement) as well as from commercial activities (e.g., royalty income from patents). Unfortunately, desire for "salary" may not exactly reflect the importance that individuals assign to other sources of financial income. We assume that these preferences are, however, positively correlated (i.e., that individuals who state a high importance of salary also care strongly about income more generally).

[6] We can reject the equality of coefficients of motives in the life sciences and physical sciences ($Chi^2(4) = 21.88$, $p < 0.01$), the life sciences and engineering ($Chi^2(4) = 13.77$, $p < 0.01$), and the physical sciences and engineering ($Chi^2(4) = 26.70$, $p < 0.01$).

[7] In one of our interviews (see the online appendix), an accomplished physicist likened patenting to "writing a textbook" in the sense that both may result in extra income but do little to further one's career. He noted, however, that "this is different in engineering. . .those guys like patents."

[8] In the words of the late Susan Lindquist, who was a pioneer in the study of protein folding: "Patenting activity is necessary for my life's work to make a difference. . .In the early 1980's, scientists did not realize that. Now they do." This was quoted by Marie Thursby at the 2010 Danish Research Unit for Industrial Dynamics (DRUID) debate on academic entrepreneurship (http://www.druid.dk/index.php?id=20).

[9] Such work could build on a large body of research in areas such as education, which has studied how people become "interested" in some subjects rather than others (Silvia 2006, Sauermann and Franzoni 2013), as well as research studying what level of difficulty and challenge people chose when setting goals (Locke and Latham 2006).

[10] However, the income motive is marginally statistically significant in the *ANYPAT* regression among physical scientists (Table 2, Model (5)), suggesting that expected income tied to commercial work may also compensate physical scientists for the opportunity costs of doing commercial activity.

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