Research Policy 39 (2010) 422–434

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

A taste for science? PhD scientists' academic orientation and self-selection into research careers in industry

Michael Roach[a,1], Henry Sauermann[b,*,1]

[a] Kenan-Flagler Business School, The University of North Carolina, Chapel Hill, NC 27599, USA
[b] College of Management, Georgia Institute of Technology, 800 W. Peachtree Street, Atlanta, GA 30308, USA

ARTICLE INFO

Article history:
Received 29 July 2009
Received in revised form
25 December 2009
Accepted 11 January 2010
Available online 10 February 2010

Keywords:
Industrial R&D
Academic science
Motives
Taste for science
Career choice

ABSTRACT

Recent research on industrial and academic science draws on the notion that academically trained scientists have a strong "taste for science". However, little attention has been paid to potential heterogeneity in researchers' taste for science and to potential selection effects into careers in industry versus academia. Using survey data from over 400 science and engineering PhD students, we examine the extent to which PhD students' taste for science (e.g., desire for independence, publishing, peer recognition, and interest in basic research) and other individual characteristics predict preferences for research careers in industry versus academia. Our results suggest that PhD students who prefer industrial employment show a weaker "taste for science", a greater concern for salary and access to resources, and a stronger interest in downstream work compared to PhD students who prefer an academic career. Our findings have important implications for innovation research as well as for managers and policy makers.

1. Introduction

Over the past decade there has been a growing interest in the role of academically trained industrial scientists in firm innovation and performance. Much of this research has focused on industrial scientists as conduits for accessing university research and as enhancing a firm's absorptive capacity (Cockburn and Henderson, 1998; Zucker et al., 1998, 2002; Gittelman and Kogut, 2003; Roach, 2009). Studies have also shown that firms try to attract high-performing graduates by creating "academic environments", e.g., by offering opportunities to publish and interact with the larger scientific community, and that academic scientists increasingly exploit entrepreneurial opportunities (Stern, 2004; Stuart and Ding, 2006; Bercovitz and Feldman, 2008; Ding, 2009). Finally, scholars have begun to examine more systematically the relationships between industrial scientists' motives and incentives and their innovative activities (Sauermann and Cohen, 2008; Haeussler, 2009).

An underlying theme in much of this research is that academically trained scientists have a strong "taste for science", e.g., preferences for upstream research, for freedom in choosing research projects, publishing, and interactions with the scientific community, while industrial employers tend to restrict such activities (Kornhauser, 1962; Blume, 1974; Stern, 2004; Aghion et al., 2008; Lacetera, 2009). Consequently, it has been argued that relaxing such constraints should increase industrial scientists' interactions with the scientific community and also make industry a more attractive career option for future cohorts of PhDs. This focus on firm policies as drivers of scientists' research activities ignores potential heterogeneity across researchers and, in particular, self-selection into industrial versus academic careers. We suggest that those PhDs who self-select into industrial careers may be less interested in finding their own research projects, interacting with other scientists at scientific conferences, or publishing and keeping up with the broader literature than those PhDs who decide to pursue an academic career. While recent empirical work has begun to contrast academic and industrial scientists along a range of dimensions (Sauermann and Stephan, 2009), PhDs' career choices and their self-selection into industrial R&D as a potential driver of differences across sectors have been virtually unexplored.

To address this gap, we study PhD students' preferences for employment in industry versus academia and examine to what extent those students aspiring to an industrial career differ systematically from those seeking employment in academia. We surveyed over 400 PhD students in science and engineering fields at three Tier 1 research universities in the United States. Using this unique survey data set, we can gain deeper insights into the career choice process at a very early stage, i.e., prior to the actual decision, rather than inferring drivers of employment choices ex post from observed employment patterns. Our empirical strategy is to relate

* Corresponding author. Tel.: +1 404 385 4883.
E-mail addresses: michael.roach@unc.edu (M. Roach), henry.sauermann@mgt.gatech.edu (H. Sauermann).
[1] These authors contributed equally to this work.

0048-7333/$ – see front matter
doi:10.1016/j.respol.2010.01.004

students' preferences for employment in industry and academia to a range of variables including respondents' preferences for various job attributes (e.g., how important is freedom to me?), students' expectations regarding the actual availability of those job attributes in different types of careers, students' desired type of research, perceived availability of different types of positions, departmental norms regarding employment in industry and academia, and students' publishing and patenting performance.

We find that PhDs' preferences for various job attributes significantly predict a preference for employment in industry versus academia, while expectations regarding the actual availability of job attributes have little effect. More precisely, we find that students with a strong "taste for science"—in particular, a strong preference for freedom to choose research projects and the ability to publish as well as the desire to conduct basic research—strongly prefer academic careers over careers in industry. On the other hand, individuals concerned with salary and access to resources, as well as the desire to conduct downstream applied research and development are more likely to prefer careers in established firms. Individuals who value responsibility are more likely to prefer employment in startups over employment in academia, while those concerned with job security are significantly less likely to prefer a career in startups. Although students' prior patenting activity does not predict career preferences, individuals with more publications are more likely to prefer academic employment. Finally, while students' expectations regarding the availability of job attributes in industry and academia have little association with their career preferences, a descriptive analysis of these expectations suggests that PhDs consider academic and industrial research careers to be very different, and no less so in the life sciences than in the physical sciences or engineering.

Although we do not observe actual career transitions, our results raise the possibility that PhDs who work in industry may have a weaker "taste for science" than academic scientists. Hence, the simplifying assumption that all academically trained scientists share a "taste for science" may be misleading and future work should consider the *strength* of a taste for science and how it relates to outcomes of interest. For example, it is conceivable that "open science" activities of firms are constrained not only by firm policies but also by a low desire of industrial scientists to engage in such activities. Our findings contribute to research on the management of innovation, scientific labor markets, and university-industry knowledge flows, while also suggesting concrete implications for managers and policy makers.

2. Background

2.1. Science and engineering PhDs and firm innovation

Upon entering industrial employment, PhDs bring with them knowledge and skills that often reflect the frontiers of science and technology in their particular fields (Rosenberg, 1985; Brooks, 1994; Cockburn and Henderson, 1998; Cohen et al., 2002; Stephan, 2006). PhD scientists and engineers tend to be engaged in upstream research and are responsible for a disproportionate share of the patent and publication output in firms (Sauermann and Cohen, 2008). A particularly important aspect of the work of PhDs employed in industry is the nurturing of ties with the broader scientific community, e.g., via publishing, memberships in professional societies, as well as attendance at professional meetings (Cockburn and Henderson, 1998; Sauermann and Stephan, 2009). By doing so, PhDs provide firms with access to critical knowledge channels and are likely to be key determinants of a firm's absorptive capacity (Cohen and Levinthal, 1990; Cockburn and Henderson, 1998; Roach, 2009).

Research on these "open science" activities in industry typically focuses on firms' policies as primary constraints, implicitly assuming that industrial scientists have a strong preference for engaging in these activities (Henderson and Cockburn, 1994; Stern, 2004; Aghion et al., 2008). Stern's (2004) seminal study has established that industrial scientists have a "taste for science". However, this study also suggests that not all of them do so to the same degree—while some scientists value publishing enough to "pay" for it, others are willing to take contracts that offer more money instead of publishing. This interpretation of Stern's study raises the question of whether there is also a systematic self-selection in the sense that scientists with a weaker taste for science are more likely to enter the industrial sector while those with a strong taste for science pursue careers in academia. If such self-selection leads to a relatively weak taste of science in industry, scientists' lack of a desire to engage in "open science" activities should be considered as a potential constraint in addition to any firm policies discouraging such activities.

Thus, it seems critical to gain a better understanding of how academically trained PhDs decide to seek employment in industry. Of particular interest is a deeper understanding of how graduating PhDs perceive differences in careers between industry and academia with respect to opportunities to engage in "open science" and if those PhDs who prefer an industry career differ systematically from those preferring a career in academia with respect to different facets of the "taste for science", e.g., their preferences for upstream research, publishing, peer recognition, intellectual challenge, and intellectual freedom.

2.2. Prior research on S&E PhD employment choices

A considerable body of research has investigated innovative activities of established scientists and engineers working in industry and academia, or at the intersection between the two sectors (Zucker et al., 2002; Thursby and Thursby, 2004; Bercovitz and Feldman, 2008; Sauermann and Cohen, 2008). However, few studies have examined the initial decisions of junior scientists to pursue careers in industry or academia. The existing empirical research on scientific careers has emphasized the role of aggregate demand and supply but tends to overlook individuals' preferences and self-selection. For example, using survey data and data from the Survey of Doctorate Recipients, Fox and Stephan (2001) find that the number of students aspiring to become faculty members is larger than the number of those who will actually find employment in that sector, suggesting imbalances in the scientific labor market (see also Regets, 1998; Davis, 2005). However, while providing important descriptive data on career patterns of science and engineering PhDs, this aggregate perspective does not address the career choice process at the level of the individual and provides limited insights into the role of individual differences such as in researchers' "taste for science" as potentially important factors affecting career trajectories.

2.3. How do careers in industry and academia differ?

Academia has traditionally been seen as the most desirable place to conduct science, offering faculty members a high degree of freedom, sufficient resources to conduct research, as well as job security. While salary and other forms of pecuniary benefits have always mattered to academics (Stephan and Levin, 1992) they were typically seen as less important than in commercial science. The primary rewards in academic science are said to be related to reputation and recognition in the community of scholars, embedded in a broader set of norms emphasizing priority in discovery, openness and sharing, and academic freedom (Merton, 1973; Dasgupta and David, 1994; Stephan, 1996; Sorenson and Fleming, 2004).

The attractiveness of academic positions may have decreased in recent years, however. One claim is that it has become more difficult to obtain resources and that academics have to spend a considerable amount of time to secure funding from outside agencies and sponsors (Hackett, 1990). It has also been argued that this dependence on funding agencies has constrained academics' freedom in choosing research topics because of the strong interest some funding agencies have in the direction of the research (Hackett, 1990; Vallas and Kleinman, 2008). Universities' increasing interest in commercial activities, including patenting, licensing, and sponsored research may also impose additional constraints and result in pressures that are not typically associated with "open science". In particular, faculty may have to spend time dealing with technology transfer offices and firms, and it is increasingly common for academic scientists to delay the publication of research results due to commercial considerations (Murray and Stern, 2007). Finally, the institution of tenure is losing some of its traditional benefits, especially in medical schools, where tenure increasingly comes without guaranteed salary and research funds (Bunton and Mallon, 2007). While these trends are likely gradual, they suggest the potential for a departure from the norms of science and a deterioration in some job attributes that academics have traditionally valued (Argyres and Liebeskind, 1998; Owen-Smith and Powell, 2001; Slaughter and Rhoades, 2004).

Industry, on the other hand, has long offered higher salaries to scientists and engineers, and this salary gap remains one of the key advantages of employment in industry (Sauermann and Stephan, 2009). Observers also claim that industry has become more attractive with respect to research funding, especially considering the deteriorating funding conditions in academia (Hackett, 1990; Vallas and Kleinman, 2008). While industry and academia have historically offered very different research environments, it has been suggested that the sectors are converging in various ways and that industry has become more desirable with respect to certain nonpecuniary job attributes. First, recognizing the potential benefits of R&D employees' involvement with the scientific community, many firms now allow their scientists and engineers to interact with the scientific community and some even structure incentives and rewards to encourage professional activities. For example, some firms in the biomedical domain explicitly consider publishing and other professional activities in their promotion decisions and there is some evidence that firms that do so tend to be more innovative (Henderson and Cockburn, 1994; Cockburn and Henderson, 1998; Stern, 2004; Ding, 2009).

Firms may also offer significant levels of freedom to their PhD scientists, especially to those engaged in more exploratory kinds of research (Vallas and Kleinman, 2008). Moreover, there is evidence that some firms actively try to signal such an "academic" atmosphere to graduating students (Henderson, 1994; Copeland, 2007). For example, in a recent article in the magazine of the American Society for Biochemistry and Molecular Biology, a GSK senior researcher explicitly points out several "misconceptions" about a scientific career in the biomedical industry and suggests that researchers have, within broad limits set by the general objectives of the company, a considerable amount of freedom, very good funding to pursue their research, and plenty of opportunities to publish and present research findings (Copeland, 2007). Despite these potential improvements, however, long-held concerns regarding industry employment may remain valid and salient to graduates. For example, despite the possibility that industrial R&D has become more open, firms still rely on secrecy to appropriate the returns from their innovations (Cohen et al., 2000). This may limit scientists' ability to openly disclose and share research results and to participate in the broader scientific enterprise.

While much of the discussion on industrial science focuses on R&D in large established firms, science may look somewhat different in startup organizations. Prior studies have shown that small and young firms tend to offer lower salaries and lower levels of job security (Oi and Idson, 1999; Carroll and Hannan, 2000; Brown and Medoff, 2003) while potentially offering more independence, intellectual challenge and more opportunities to take on responsibilities (Idson, 1990; Sauermann and Stephan, 2009). To the extent that startup firms have academic roots (e.g., founded by faculty members), they may also have a more "academic" atmosphere, potentially allowing their employees to interact more freely with the scientific community (Etzkowitz, 1998; Zucker et al., 2002; Gittelman and Kogut, 2003; Owen-Smith and Powell, 2004; Ding, 2009). Thus, within industry, startups may offer somewhat different work environments than established firms, in particular, more opportunities to participate in "open science".

2.4. Conceptual model of career preferences

In line with prior work on decision making and career choice, we conceptualize each career option (e.g., employment in academia or in an established firm) as characterized by a vector of attributes such as pay, intellectual freedom, opportunities to publish, or availability of funding (Rosen, 1986; Payne et al., 1993; Sauermann, 2005). A first set of factors that may influence students' preferences for employment in industry versus academia (our key dependent variable) are students' *preferences for particular job attributes*, i.e., what they care about and what they are looking for in a job. For example, some graduates might care strongly about high salary, while others may find it more important to be able to make independent decisions about their research agenda. Students with stronger preferences for a particular attribute should be more likely to prefer the option that offers relatively more of that attribute.

Second, career choices may depend on students' *expectations regarding the particular characteristics of different career options*, e.g., regarding the levels of pay and freedom available in academia or in established firms. PhD students may form expectations regarding these attributes as a byproduct of other activities (e.g., by observing advisors, casual conversations with friends, etc.) but may also purposefully collect such information, e.g., by attending career fairs or participating in internships designed to provide exposure to industry. Theoretically, expectations regarding job attributes and individuals' preferences regarding those attributes should interact in the sense that stronger preferences increase the effects of expectations on career preferences. Note that expectations regarding the characteristics of employment options may be inaccurate; however, even inaccurate expectations may affect choices.

Third, PhD candidates' preferences for industry and academic employment may also be shaped by *social influences and norms* in their departments and larger social environment (cf. Stuart and Ding, 2006; Azoulay et al., 2007; Bercovitz and Feldman, 2008). Some fields and some institutions have a longer history of industry employment, which may affect what PhD students perceive as "acceptable" or "desirable" jobs. Finally, while we are primarily interested in students' career preferences regardless of labor market conditions, it is likely that students' preferences are shaped by the perceived *availability of positions*. For example, faculty positions are in short supply in many fields (Fox and Stephan, 2001; Davis, 2005) and students might rate an academic career as less attractive because of the anticipated struggles to obtain a tenure-track position and, ultimately, tenure. Again, it is not the actual supply of positions that matters, but students' perceptions of what the labor market looks like.

In the following empirical section of this paper, we use survey data from over 400 science and engineering PhD students to provide descriptive data on students' preferences for a range of job attributes, on students' expectations regarding the actual attributes of careers in industry and academia, and about their preferences for research careers in established firms, startup firms, and academia. We then examine to what extent career preferences are associated with the other key variables.

3. Data and measures

3.1. Sample and survey methodology

We surveyed students pursuing a PhD in science or engineering fields at three major research universities in the U.S. state of North Carolina, including one private and two public institutions. We chose to survey current PhD students rather than currently employed PhDs to obtain responses on career preferences prior to the actual employment decision. Thus, our data enable us to gain direct insights into PhDs' career decision processes and we do not have to rely on retrospective reports or on indirect inferences based on ex post employment patterns.

We approached respondents using a mixed-mode strategy (Dillman, 2007). First, we attended the "North Carolina Science and Engineering Career Fair", which is an annual event jointly organized by the career centers of the three universities and which attracts many non-academic employers. Second, we contacted the graduate student administrators at science and engineering departments at one of the three institutions and asked them for permission to distribute printed questionnaires with return envelopes to the graduate students' mail boxes or labs. All administrators agreed and the survey packets were distributed by either the researchers or the administrators. After approximately 3 weeks, we asked the administrators to forward a reminder email to students; the email also included a link to the online version of the survey. We conducted the surveys at the other two institutions exclusively in the online mode. For that purpose, we contacted departmental administrators by email and asked them to forward an email with a description of the survey and the appropriate link to their graduate students. All administrators were asked to forward a reminder email 12 days after our initial request.

Overall, we obtained 472 responses from students who were currently enrolled in a science or engineering PhD program. The response rate at the career fair was very high; almost all students we approached completed the survey while at the fair. We are not able to calculate the response rate for questionnaires distributed by administrators at the campuses, however, because we cannot establish reliably which administrators forwarded our requests and how many students received it. We conducted a non-response analysis based on the number of missing items in the online survey (Rogelberg and Stanton, 2007); these tests show that students closer to graduation tend to have fewer missing items, suggesting that more advanced students may also have been more likely to respond to the survey.[2] For the analyses reported in this paper, we excluded 46 cases because they were either missing key information (e.g., field of study) or because they were missing a large number of variables, leaving us with 426 useable cases.

For these remaining 426 cases, we imputed missing data using multiple imputation, which is currently the most advanced general purpose method to account for item non-response (Rubin, 1987; King et al., 2001; Schafer and Graham, 2002; Fichman and Cummings, 2003). In multiple imputation, missing data fields are predicted based on regression equations estimated using the complete cases and including a random draw from an error distribution. This process is repeated multiple ($m = 8$) times in order to generate variation around the prediction, reflecting the uncertainty associated with missing data. Regression models are then estimated from all imputations and estimates are averaged with appropriate adjustments to standard errors. While other imputation methods such as mean substitution or hotdeck imputation artificially reduce the standard errors around estimates, multiple imputation avoids this bias by virtue of using multiple predictions for each missing value.

[2] Approximately 70% of the students in our final sample were in the third or a higher year of their PhD program.

3.2. Measures

Our survey instrument included closed-ended as well as open-ended questions. We will first provide a more detailed discussion of our key measures and will then provide an overview of other measures. Descriptive statistics are provided in Table 1; Table 2 shows correlations. The open-ended questions are discussed in the analysis section.

3.2.1. Attractiveness of career options

Our primary dependent variables are measures of the attractiveness of three distinct research career paths: an R&D position in an established firm, an R&D position in a startup firm, and a faculty position at a university. We asked students "*How attractive would you personally find* each of the following employment options after graduation, assuming you have the choice?" Students rated each career option on a 5-point scale (1 = not attractive, 5 = very attractive).

3.2.2. Preferences for job attributes

We asked students "When thinking about employment after graduation, *how important* to you are the following job attributes?" Respondents rated the importance of 10 job attributes on a 5-point scale (1 = not important, 5 = very important). The 10 job attributes were chosen based on prior work (e.g., Stern, 2004; Sauermann and Stephan, 2009) and on our own interviews with industrial and academic scientists and include: salary and benefits, availability of funding and resources, availability of cutting-edge technologies/equipment, job security, responsibility on the job, intellectual challenge, ability to gain peer recognition, ability to collaborate with other institutions/organizations, ability to present and publish research, and freedom to choose projects.

Given that a number of our preference attributes are conceptually related, we created two index measures (cf. Stern, 2004) to simplify the regression analysis and to make the results more easily interpretable. First, we suggest that the job attributes "freedom to choose projects", "opportunities to publish and present research", "collaborate with others outside the organization" and "opportunity to gain peer recognition" all are traditionally associated with academic science (Merton, 1973; Stern, 2004; Wuchty et al., 2007). Thus, we averaged students' ratings of the importance of these attributes to create an index measure of their "taste for science". Second, we averaged students' preferences for "availability of funding" and "access to cutting-edge technologies and equipment" to reflect students' desire for access to resources.[3]

3.2.3. Additional featured variables and controls

Our survey also included questions regarding other factors that may have significant effects on students' career choices. In particular, we asked students about their perceptions of the job attributes available in the different kinds of careers, about their research performance (patent and publication counts) and how interested they

[3] We also created equivalent index measures of students' expectations regarding the availability of these job attributes (see below). We chose to create all index measures using a simple average rather than weighted averages derived from factor analyses because simple averages ensure that the indices are comparable and interpretable across career options.

Table 1
Descriptive statistics.

	Variable name	Type	Mean	SD	Min	Max
Attractiveness of careers	Established firm	5-Point	3.51	1.37	1	5
	Startup	5-Point	2.90	1.28	1	5
	Faculty	5-Point	3.49	1.42	1	5
Most attractive career	Established firm	Dummy	0.57	0.50	0	1
	Startup	Dummy	0.29	0.45	0	1
	Faculty	Dummy	0.55	0.50	0	1
Preferences for job attributes	Intellectual challenge	5-Point	4.37	0.71	2	5
	Funding and resources	5-Point	4.25	0.93	1	5
	Job security	5-Point	4.11	0.89	1	5
	Salary and benefits	5-Point	4.04	0.86	1	5
	Responsibility	5-Point	3.94	0.78	1	5
	Freedom to choose	5-Point	3.77	1.07	1	5
	Cutting-edge tech/equip	5-Point	3.71	1.03	1	5
	Ability to collaborate	5-Point	3.70	1.08	1	5
	Publishing	5-Point	3.54	1.26	1	5
	Peer recognition	5-Point	3.27	1.04	1	5
Work desired	Basic	5-Point	3.49	1.26	1	5
	Applied	5-Point	3.98	1.17	1	5
	Development	5-Point	3.24	1.27	1	5
	Management	5-Point	2.55	1.33	1	5
Availability of jobs	Established firm	5-Point	3.12	0.97	1	5
	Startup	5-Point	2.83	0.95	1	5
	Faculty	5-Point	2.51	0.91	1	5
Norms	Established firm	5-Point	3.20	1.14	1	5
	Startup	5-Point	2.46	1.08	1	5
	Faculty	5-Point	3.07	1.29	1	5
Performance	Patents yes/no	Dummy	0.07	0.25	0	1
	Publications	Count	2.23	2.53	0	18
Major field	Life sciences	Dummy	0.56	0.50	0	1
	Physical and applied sciences	Dummy	0.30	0.46	0	1
	Engineering	Dummy	0.14	0.35	0	1
Controls	Years in program	Count	3.55	1.70	1	8
	Male	Dummy	0.46	0.50	0	1
	Married	Dummy	0.42	0.49	0	1
	Nationality USA	Dummy	0.78	0.42	0	1

are in working on different types of R&D (e.g., basic, applied, development). We obtained information about departmental norms regarding career choices by asking respondents how common it is for graduates in their department to pursue each of the different career options. Finally, we asked students about their perceptions of labor market conditions by asking them to rate the availability of jobs in academia, startups, and established firms in their particular field.

4. Results

4.1. Key descriptive results

4.1.1. Expectations regarding job attributes

We asked our respondents to rate on a 3-point scale (1 = low, 3 = high) the extent to which they thought the 10 job attributes were available in an established firm, startup, and university, respectively. In order to assess respondents' level of information about the three employment options, we also included a "Don't know" box. Table 3 shows that PhDs checked this box quite frequently for established firms (average 10%) and for startups (average 15%), while only rarely for universities (1%). This is consistent with our expectation that PhDs feel much better informed about the characteristics of employment in academia than industry. A comparison of the "don't know" response frequency across job attributes shows that PhDs felt generally best informed about salary levels and least informed about the degree to which organizations allow scientists to collaborate with outsiders.

Table 3 also shows that established firms are seen as particularly strong with respect to job attributes that require resources: salary and benefits, access to cutting-edge technology, and funding. The attributes judged as least available are freedom to choose projects, the ability to present and publish research, and the ability to collaborate with outsiders. Students seem to think of startups as offering quite low levels of almost all attributes except responsibility and intellectual challenge. While startups are judged as offering significantly higher levels of freedom and ability to publish than established firms, the perceived advantage is relatively small.

Expectations regarding university employment look quite different. The highest ranked items are the ability to present and publish research, the ability to collaborate with outsiders, and intellectual challenge; salary and funding and resources are judged least readily available.

The last column in Table 3 shows the difference between expectations for established firms and for universities; i.e., the perceived advantages and disadvantages of these two careers. We see that, conditional upon respondents having sufficiently defined expectations for both established firms and university, firms tend to be perceived as clearly superior with respect to salary and resources, while universities have a strong advantage with respect to collaboration, freedom to choose projects, and the ability to publish.

An interesting question is whether the perceived differences between employment in established firms and in academia are smaller in the life sciences, reflecting a "convergence" of the research environments in industry and academia (Vallas and Kleinman, 2008). In Fig. 1, we show the difference in expecta-

Table 2
Correlations.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Attractiveness of established firm																
2. Attractiveness of startup	0.6532*															
3. Attractiveness of faculty	−0.3332*	−0.2537*														
4. Basic research	−0.1378*	−0.1292*	0.3100*													
5. Applied research	0.3840*	0.2596*	−0.0963*	0.1122*												
6. Development	0.5311*	0.4169*	−0.2514*	−0.1407*	0.4250*											
7. Management	0.2315*	0.2020*	−0.1089*	−0.3139*	0.1383*	0.2861*										
8. Pref: Intellectual challenge	−0.0881	0.0213	0.1527*	0.2347*	0.0984*	0.0100	−0.0350									
9. Pref: Ability to collaborate	−0.1273*	−0.0498	0.2879*	0.3827*	0.1934*	−0.0070	0.0092	0.3086*								
10. Pref: Cutting-edge tech/equip	0.2430*	0.2124*	0.0029	0.2379*	0.2774*	0.2541*	0.0440	0.3655*	0.4164*							
11. Pref: Freedom	−0.2517*	−0.1474*	0.3733*	0.3886*	0.0814	−0.0537	−0.0550	0.4738*	0.4985*	0.2524*						
12. Pref: Funding	0.0760	−0.0065	0.1815*	0.3886*	0.2955*	0.0823	−0.0569	0.2464*	0.4528*	0.4655*	0.3986*					
13. Pref: Publishing	−0.2023*	−0.1682*	0.4031*	0.5202*	0.1700*	−0.1232*	−0.1369*	0.4096*	0.6117*	0.3839*	0.6382*	0.5331*				
14. Pref: Peer recognition	−0.0361	−0.0731	0.1530*	0.2245*	0.0574	0.0540	0.1282*	0.3060*	0.4256*	0.3588*	0.3964*	0.2996*	0.4931*			
15. Pref: Responsibility	0.1822*	0.1361*	0.0443	−0.0393	0.1956*	0.1954*	0.2673*	0.3393*	0.1499*	0.2373*	0.1892*	0.1683*	0.1717*	0.3328*		
16. Pref: Salary	0.3064*	0.1538*	−0.0701	−0.0803	0.1625*	0.2054*	0.1773*	−0.0282	−0.0555	0.1798*	−0.0636	0.1313*	−0.0685	0.0585	0.2989*	
17. Pref: Job security	0.1804*	−0.0121	0.0456	0.1129*	0.2320*	0.1819*	−0.0108	0.0287	0.1216*	0.1423*	0.1110*	0.1942*	0.1138*	0.1625*	0.3122*	0.4283*

* Significant at 5%.

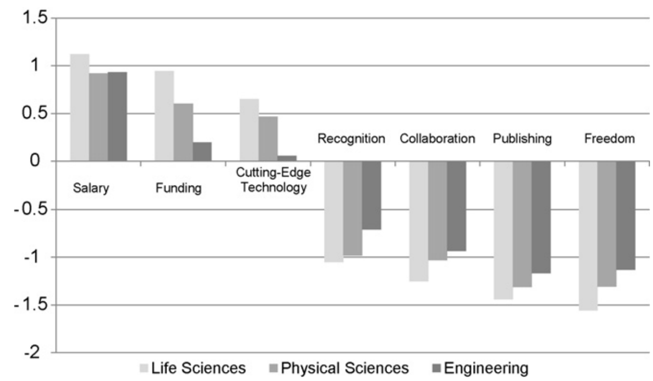

Fig. 1. Difference in expectations (established firm–academia) by field.

tions (established firm–academia) by broadly defined field for key attributes and find only small differences across the life sciences, physical sciences, and engineering. Surprisingly, the perceived differences between research in established firms and in academia tend to be somewhat *larger* in the life sciences than in other fields, and the perceived industry–academia gap with respect to funding and freedom is significantly larger in the life sciences than in engineering. Thus, the life sciences students in our sample do not seem to think of industry and academia as being any less different than the students in other fields.

We also elicited expectations regarding employment in industry versus academia using an open-ended question. In particular, we asked respondents "What would you *dislike* most about a career in an established firm, startup, and a university?" Some particularly interesting (though not necessarily representative) responses include:

Established firm

- "Inability to pursue an interesting project if money leads the company elsewhere".
- "Just another nameless face, routine, boredom".
- "Restriction of projects and/or limited chance to share/publish".
- "The inability to work with everyone and following the chains of command".
- "Not being awarded respect for my time and personal life".

Startup firm

- "High probability of tension and frustration due to unstable environment (many scientists are NOT good at starting up businesses!)".
- "Questions about long-term viability of the firm".
- "Low job security, potentially low salary".
- "May have to wear many hats rather than have specific responsibilities".
- "Not having prestige of established firm".

University

- "The constant struggle and competition to get funding".
- "Pressure to publish; colleagues overly concerned with prestige".
- "Lack of support for components of career other than research, the publication or perish problem".
- "Professors are AWFUL managers and don't try to improve".
- "Too much management involved: you are the team leader, instead of the researcher".

We coded the answers to these questions to reflect a smaller set of common issues. The overriding concern about employment

Table 3
Expectations regarding the availability of job attributes in different careers (3-point scale).

	Established firm		Startup		University		Estab-Univ.
	Mean	Don't know	Mean	Don't know	Mean	Don't know	
Salary and benefits	2.87	7%	1.95	12%	1.84	1%	1.04
Cutting-edge tech/equip	2.71	9%	1.95	14%	2.20	2%	0.51
Funding and resources	2.64	10%	1.68	15%	1.90	2%	0.73
Responsibility	2.42	8%	2.80	13%	2.64	1%	−0.22
Job security	2.27	8%	1.22	11%	2.44	1%	−0.17
Intellectual challenge	2.22	9%	2.71	13%	2.87	1%	−0.65
Peer recognition	1.80	13%	1.90	17%	2.78	1%	−0.98
Ability to collaborate	1.74	14%	1.94	19%	2.88	2%	−1.14
Publishing	1.60	11%	1.77	17%	2.96	1%	−1.36
Freedom to choose	1.33	12%	1.82	15%	2.75	1%	−1.43
Mean	2.16	10%	1.97	15%	2.53	1%	−0.37

in established firms appears to be the perceived lack of freedom in various forms, which was mentioned by 32% of the respondents. The largest concern about employment in startups is the lack of stability and job security, cited by 71% of the respondents. The main concerns about university employment are funding shortages and low pay, cited by 22 and 16% of the respondents, respectively.

In interpreting the results reported in this section, it should be noted that students' expectations may be inaccurate and even systematically biased, especially regarding industry careers. We cannot assess the accuracy of students' expectations. However, even inaccurate expectations may have significant impacts on students' job search activities and career choices.

4.1.2. *Preferences for job attributes*

The means of respondents' preferences for job attributes are shown in Table 1. Intellectual challenge, funding, job security, and salary are generally considered most important, while peer recognition and publishing are among the least important attributes. The latter finding is particularly interesting because it suggests that at least some PhDs do not have strong preference for these factors commonly associated with the scientific enterprise. Moreover, the preference measures show a considerable amount of variation, suggesting significant individual differences in these preferences and thus the potential for self-selection. There are only minor differences in the importance of job attributes across fields.

4.1.3. *Attractiveness of positions*

Table 1 shows the means of our measures of the attractiveness of careers in established firms, startups, and academia, respectively. Across all fields, we find that research careers in established firms and in academia are judged as similarly attractive, while research careers in startups are rated as much less attractive. Fig. 2 visualizes students' implicit choices, e.g., how often each of the three careers was rated as the *most* attractive option.[4] Fig. 2 also distinguishes between the three broadly defined fields of the life sciences, physical sciences, and engineering. Life scientists find academia and established firms similarly attractive; physical scientists find academia somewhat more attractive than established firms, and engineers find jobs in established firms more attractive. Startups are generally considered least attractive.

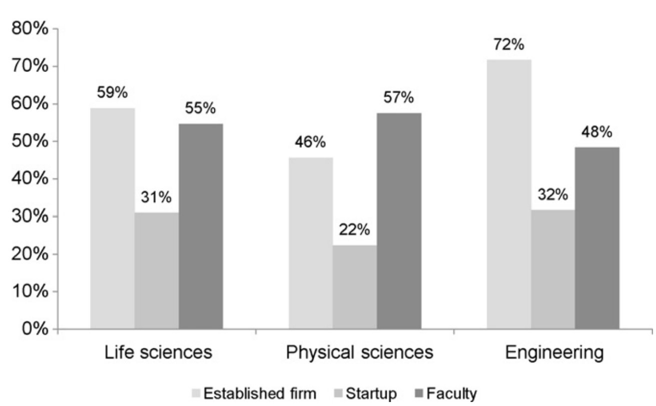

Fig. 2. Most attractive career option (ties possible).

4.2. *Model specifications and regression results*

4.2.1. *Attractiveness of employment options*

Our first set of models uses the attractiveness ratings for the three career options as dependent variables and is estimated using ordered logit. These regressions estimate the determinants of the attractiveness of a particular career path, independent of the judged attractiveness of alternative careers. For example, the attractiveness of a research career in an established company would be specified as

$$\begin{aligned} \text{ATTR\_EST}_i = f(&\beta_0 + \beta_1 \text{PREF}_i + \beta_2 \text{AVAIL\_EST}_i + \beta_3 \text{NORMS\_EST}_i \\ &+ \beta_4 \text{WORK}_i + \beta_5 \text{PERFORMANCE}_i \\ &+ \beta_6 \text{CONTROLS}_i + \varepsilon_i) \end{aligned} \tag{1}$$

where PREF_i is a vector of measures of the respondent's preferences for the 10 job attributes, AVAIL_EST_i is the respondent's rating of the availability of jobs in established firms, NORMS_EST_i is the respondent's rating of departmental norms regarding jobs in established firms, WORK_i is a vector of preferences regarding different types of research, PERFORMANCE_i is a vector including prior patents and publications, and CONTROLS_i is a vector of control variables.[5] Given the limitations of cross-sectional survey data, we are unable to fully account for all potential sources of endogeneity and thus interpret regression coefficients as reflecting correlations rather than causal relationships.

Models 1 and 2 in Table 4 show the results for the attractiveness of established firms. We observe several significant coefficients on the preference variables; in particular, the importance of salary

[4] We also count ties, i.e., if established firm and startup are both rated a 4 on the attractiveness scale and academia a 3, then both established firm and startup are coded as the most attractive option.

[5] We also estimated models including the measures of respondents' expectations of job attributes and the interactions between preferences and expectations (e.g., expectation of salary in established firm interacted with the importance of salary). The interaction terms were generally not significant and the measures of expectations tended to have only weak effects. We exclude the measures of expected job attributes from our featured ordered logit models, but we include these measures in the alternative-specific logit regressions that follow.

Table 4
Attractiveness of careers (ordered logit).

	Established firm		Startup		Faculty	
	1	2	3	4	5	6
Preference for attribute						
Salary	0.370**	0.389**	0.180	0.168	0.008	−0.007
	[0.138]	[0.139]	[0.130]	[0.131]	[0.132]	[0.129]
Job security	0.079	0.060	−0.348*	−0.348*	0.123	0.098
	[0.139]	[0.139]	[0.140]	[0.140]	[0.139]	[0.137]
Intellectual challenge	−0.021	−0.077	0.177	0.138	−0.100	−0.045
	[0.177]	[0.171]	[0.185]	[0.174]	[0.180]	[0.177]
Responsibility	0.125	0.165	0.258	0.228	0.069	−0.002
	[0.164]	[0.162]	[0.171]	[0.170]	[0.167]	[0.174]
Funding	0.186		0.065		0.066	
	[0.150]		[0.138]		[0.147]	
Cutting-edge tech/equip	0.430**		0.243*		−0.177	
	[0.123]		[0.123]		[0.116]	
Freedom	−0.492**		−0.264		0.383**	
	[0.141]		[0.141]		[0.130]	
Publishing	−0.224		−0.153		0.378**	
	[0.127]		[0.127]		[0.129]	
Ability to collaborate	−0.217*		0.085		0.201	
	[0.109]		[0.125]		[0.123]	
Peer recognition	−0.071		−0.188		−0.195	
	[0.123]		[0.114]		[0.115]	
Index: Taste for science		−1.028**		−0.539**		0.797**
		[0.173]		[0.178]		[0.192]
Index: Access to resources		0.684**		0.379*		−0.109
		[0.165]		[0.159]		[0.177]
Other variables						
Availability of positions	0.108	0.114	0.127	0.145	0.100	0.066
	[0.133]	[0.131]	[0.119]	[0.117]	[0.128]	[0.122]
Norms for entering career	0.210	0.224*	0.475**	0.488**	0.118	0.127
	[0.111]	[0.112]	[0.112]	[0.110]	[0.099]	[0.099]
Number of patents	−0.351	−0.309	0.323	0.337	−0.038	−0.057
	[0.373]	[0.389]	[0.375]	[0.384]	[0.420]	[0.416]
Number of publications	−0.027	−0.026	−0.115*	−0.117*	0.068	0.072
	[0.047]	[0.047]	[0.050]	[0.051]	[0.050]	[0.049]
Basic research	0.094	0.078	0.032	0.027	0.205*	0.258**
	[0.097]	[0.098]	[0.090]	[0.091]	[0.101]	[0.094]
Applied research	0.362**	0.346**	0.200*	0.215*	−0.317**	−0.250*
	[0.116]	[0.112]	[0.099]	[0.100]	[0.109]	[0.102]
Development	0.517**	0.503**	0.390**	0.381**	−0.231*	−0.270*
	[0.103]	[0.098]	[0.106]	[0.103]	[0.111]	[0.110]
Management	0.033	0.052	0.037	0.052	0.015	−0.019
	[0.088]	[0.087]	[0.087]	[0.087]	[0.085]	[0.083]
Male	−0.205	−0.246	0.405*	0.367	0.063	0.165
	[0.202]	[0.200]	[0.203]	[0.197]	[0.203]	[0.196]
Nationality	−0.531	−0.588	0.026	0.005	−0.014	0.075
	[0.311]	[0.308]	[0.298]	[0.294]	[0.252]	[0.254]
Field dummies	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Other controls	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Observations	426	426	426	426	426	426
Chi-square	270.653	262.234	186.977	181.223	162.561	144.37

Robust standard errors in brackets.
* Significant at 5%.
** Significant at 1%.

and access to cutting-edge technology are both significantly related with greater attractiveness of working for an established firm. On the other hand, we observe a negative relationship between the preference for intellectual freedom and the ability to collaborate on the one hand and the attractiveness of working in an established company on the other. The latter result suggests that not only do academically trained scientists vary in their preference for freedom to choose their own projects and to freely collaborate, but those who care less about these attributes may self-select into industry.

We also find that individuals who are more interested in applied work or development find a research career in an established firm more attractive. Somewhat surprisingly, we do not find that individuals with prior patenting activity—often perceived to be an indicator of the commercial orientation of academic scientists—are more likely to find industry attractive. Similarly, we find no significant relationship between prior publishing and the attractiveness of a career in an established company. Departmental norms regarding employment in established firms have a positive effect, while the perceived availability of positions in established firms has no significant impact. Note that our attractiveness questions explicitly asked students to ignore the availability of positions and we include the availability measure only to control for any subconscious effects of perceived labor market conditions on students' career preferences.

In model 2, we use the index measures for students' taste for science and preference for access to resources. The results are consistent with model 1: PhDs' preference for access to resources is positively related with the attractiveness of a career in an established firm, while PhDs' "taste for science" has a negative coefficient. To illustrate the economic size of these effects, Panel A in

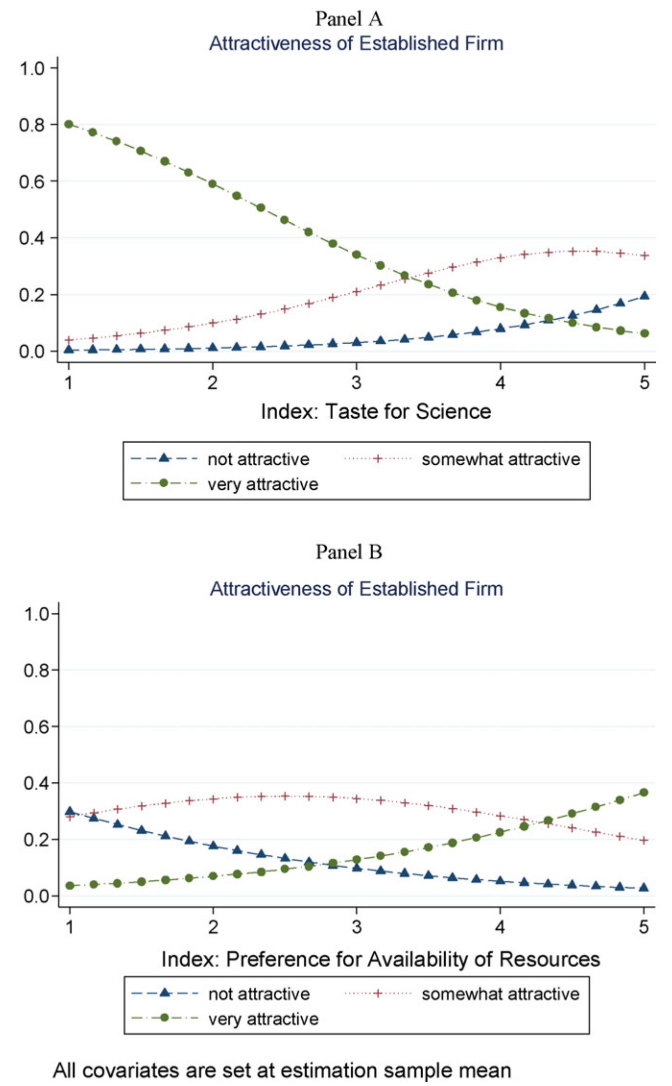

Fig. 3. Predicted attractiveness ratings of established firm, based on ordered logit regressions. *Note*: The lines in each panel represent the predicted probabilities that a respondent finds employment in an established firm not attractive (1 on the attractiveness scale), somewhat attractive (3) or very attractive (5).

Fig. 3 shows the predicted probabilities that a student finds a career in an established firm not attractive (1 on the attractiveness scale), somewhat attractive (3) or very attractive (5) as her taste for science increases from low (1) to high (5), with all other variables held at their mean. Note in particular the steep drop in the predicted probability that an individual rates a research career in an established firm as very attractive (5 on 5-point scale), which decreases from a high of 80 to 6% as taste for science increases to its maximum. Conversely, Panel B shows that the probability of a “very attractive” rating for established firms increases from 4 to 37% as students’ preference for access to resources increases to its maximum.

In models 3–4, we estimate equivalent regressions for the attractiveness of startups and also find significant effects of individuals’ preferences for job attributes. Students concerned with resources tend to rate startups as more attractive, while those with a stronger taste for science rate startups less attractive. An increase in the preference for job security is associated with a lower attractiveness of startups, consistent with our observation that many students are concerned about job security in startups. Finally, startups are rated more attractive if a career in startups has been more common in the respondents’ department in the past.

In models 5–6, we report the results for regressions of the attractiveness of a faculty career. Individuals with a stronger taste for science rate a faculty career significantly higher, whereby freedom and publishing seem to be the primary drivers. Interestingly, a concern with resources does not significantly reduce the attractiveness of a faculty career, despite growing concerns in the general discussion that funding shortages may deter students from pursuing an academic career. As expected, the more individuals are interested in basic research, the more appealing is academia, while an interest in applied work and development decrease the attractiveness of the faculty career. The degree to which individuals want to be engaged in management is not associated with the attractiveness of either of the three career options. This is consistent with the idea that research in industry as well as in academia may involve management, be it as team leader in a firm or as lab director in academia (see also some management related quotes in Section 4.1.1 above).

4.2.2. Choice between alternative career options

The regressions reported in the previous section utilized the measures of career attractiveness independently for each career. Thus, they examined which factors make a particular career attractive (or unattractive) to an individual. We will now turn to the question of which factors make industry careers more or less attractive *relative* to a career in academia, thus more explicitly addressing the issue of career choice.[6] For that purpose, we computed measures of relative preferences that capture the choices implicit in individuals’ attractiveness ratings, i.e., which option the respondent rates as *most* attractive (see also Fig. 2). We created three new dummy variables that take on the value of 1 if the respective career had the highest (or among the highest) attractiveness score. The three new variables are ideally suited to be analyzed using alternative-specific conditional logit (McFadden, 1974) as implemented in Stata’s ASCLOGIT command. A key strength of this approach is that it allows us to model the effects of characteristics of the *alternatives* (e.g., levels of salary available in different careers) as well as the effects of characteristics of the *individuals* (e.g., preference for salary) on career choices.

ASCLOGIT simultaneously estimates multiple equations. One equation estimates the effects of attributes of a career option on the likelihood of that option being chosen. For example, a positive coefficient on expected level of salary would indicate that an option (no matter if the option is faculty, startup, or established firm) is more likely to be chosen if it is expected to pay a high salary. A second set of equations estimates the effects of individuals’ attributes on the likelihood of choosing a particular option, e.g., established firms versus faculty or startup versus faculty. Given three career options ($j = 1, \ldots, 3$), two such equations are estimated and we use FACULTY as the omitted category. These two equations are essentially equivalent to a multinomial logit model with FACULTY as the omitted category. Thus, the probability of a respondent i finding a particular career j most attractive is modeled as

$$\begin{aligned}\Pr(\text{MOST}_i = j) = f(&\beta_0 + \beta_1\text{EXP}_{ji} + \beta_2\text{AVAIL}_{ji} + \beta_3\text{NORMS}_{ji}\\ &+ \beta_4\text{PREF}_i + \beta_5\text{WORK}_i + \beta_6\text{PERFORMANCE}_i\\ &+ \beta_7\text{CONTROLS}_i + \varepsilon_{ji})\end{aligned} \quad (2)$$

[6] These regressions more accurately capture the notion of “choice” and complement the attractiveness regressions discussed earlier. For example, a variable X1 may increase the attractiveness of both options A and B but not lead to a change in the implied choice of A versus B. On the other hand, a variable X2 may increase the attractiveness of option A much more than that of option B and thus lead to a different choice. The attractiveness regressions alone do not reveal the effects of X’s on the choice between A and B, while the choice regressions alone do not reveal to what extent the X’s operate via the attractiveness of A versus the attractiveness of B.

Table 5
Most attractive option (alternative-specific conditional logit).

	Most attractive option (1a)	Estab. firm versus faculty (1b)	Startup versus faculty (1c)	Most attractive option (2a)	Estab. firm versus faculty (2b)	Startup versus faculty (2c)
Career attribute						
(Cols. 1a, 2a: expectations; cols. 1bc, 2bc: preferences)						
Salary	0.366	0.275	0.148	0.412*	0.259	0.170
	[0.196]	[0.284]	[0.286]	[0.190]	[0.290]	[0.290]
Job security	0.259	−0.199	−0.759**	0.232	−0.243	−0.784**
	[0.191]	[0.275]	[0.287]	[0.173]	[0.276]	[0.282]
Intellectual challenge	0.183	0.18	0.391	0.191	0.101	0.374
	[0.235]	[0.391]	[0.419]	[0.209]	[0.389]	[0.401]
Responsibility	0.187	0.254	0.757*	0.185	0.354	0.691*
	[0.218]	[0.309]	[0.309]	[0.200]	[0.318]	[0.326]
Funding	0.325	−0.354	−0.45			
	[0.210]	[0.394]	[0.354]			
Cutting-edge tech/equip	0.114	0.903**	0.733*			
	[0.215]	[0.307]	[0.287]			
Freedom	0.613**	−0.933**	−0.627*			
	[0.174]	[0.323]	[0.285]			
Publishing	−0.104	−0.511	−0.479			
	[0.237]	[0.281]	[0.267]			
Ability to collaborate	−0.136	−0.204	0.149			
	[0.225]	[0.265]	[0.259]			
Peer recognition	0.052	0.072	−0.085			
	[0.213]	[0.221]	[0.238]			
Index: Access to resources				0.348	0.929*	0.638
				[0.211]	[0.414]	[0.350]
Index: (Taste for) science				0.532*	−1.762**	−1.188**
				[0.254]	[0.412]	[0.362]
Other variables						
Availability of positions	0.092			0.115		
	[0.160]			[0.146]		
Norms for entering career	0.140			0.163		
	[0.126]			[0.114]		
Number of patents		−0.011	0.543		−0.122	0.379
		[0.791]	[0.806]		[0.760]	[0.770]
Number of publications		−0.252**	−0.271**		−0.215*	−0.243**
		[0.095]	[0.092]		[0.089]	[0.093]
Basic research		−0.25	−0.134		−0.236	−0.084
		[0.217]	[0.204]		[0.204]	[0.197]
Applied research		0.747**	0.503*		0.597**	0.392*
		[0.217]	[0.217]		[0.199]	[0.196]
Development		0.777**	0.681**		0.740**	0.654**
		[0.208]	[0.221]		[0.203]	[0.211]
Management		0.029	−0.048		0.123	0.006
		[0.178]	[0.173]		[0.172]	[0.174]
Male		−0.05	−0.125		−0.242	−0.197
		[0.483]	[0.474]		[0.452]	[0.433]
Nationality		−0.466	−0.227		−0.559	−0.419
		[0.602]	[0.582]		[0.545]	[0.552]
Detailed field dummies		Incl.	Incl.		Incl.	Incl.
Other controls		Incl.	Incl.		Incl.	Incl.
Constant		−1.745	−4.551		−3.078	−5.106
		[2.803]	[2.982]		[2.679]	[2.956]
N	426			426		

Robust standard errors in brackets.
Note: All models are estimated using alternative-specific conditional logit. Columns 1a and 2a show the effects of (perceived) characteristics of the *alternatives* on the likelihood of that (any) alternative being chosen. Columns 1b and 2b show the effects of characteristics of the *individual* on the likelihood of choosing employment in an established firm over employment in academia. Columns 1c and 2c show the effects of characteristics of the individual on the likelihood of choosing employment in startup firm over employment in academia.
* Significant at 5%.
** Significant at 1%.

where EXP_{ji} is a vector of expectations regarding the 10 job attributes in option j, $AVAIL_{ij}$ is the respondent's rating of the availability of jobs in option j, $NORMS_{ji}$ is the respondent's rating of departmental norms regarding jobs in option j, and the other terms are as defined in (1).

In model 1 in Table 5, we use the separate measures for all 10 job attributes. With respect to expectations (column 1a), we find that careers that are judged as offering a higher degree of freedom to choose projects are more likely to be judged as the most attractive careers. With respect to students' preference for employment in an established firm versus academia (column 1b), we see that individuals with a strong concern for freedom are less likely to prefer employment in an established firm over an academic career (omitted category), while those concerned with access to cutting-edge technologies are more likely to prefer a career in an established firm. A preference for startups (column 1c) is associated with a preference for responsibility and access to cutting-edge technologies, while students concerned with job security and freedom are less likely to prefer a startup over academia. Thus, even though startups are thought to offer somewhat higher levels of freedom than established firms, they still have a considerable disadvantage in that respect compared to academia, and students who care about freedom may self-select out of established firms as well as startups. Students with a high interest in applied work and development are more likely to prefer R&D in an established firm. Finally, students with a greater number of publications tend to find careers in established companies and startups less attractive relative to an academic career. Interpreting publications as a measure of performance, better students appear to prefer an academic career.[7]

In model 2, we use the index measures for students' preferences as well as expectations regarding job attributes. The results are similar to the results using the detailed measures. Most importantly, we find that a student's taste for science has a strong negative effect on the likelihood that the student considers a career in an established firm or a startup most attractive. In contrast, a student's concern with access to resources has a small positive effect on the likelihood that the student prefers a research career in an established firm over a career in academia.

4.2.3. Comparison of regression models

The results of our two sets of regressions (ordered probit models of attractiveness scores separately and alternative-specific conditional logit of most attractive options) provide complementary insights. While the ordered logit regressions of attractiveness scores reveal how students form attitudes vis-à-vis a particular career path, the alternative-specific logit regressions show which factors influence students' relative preferences for one career over another. Thus, the ASCLOGIT regressions reflect a compound effect of a particular independent variable on both the attractiveness of careers in industry and on the attractiveness of academia. By considering the results of the two sets of regressions jointly, we can learn more about the underlying drivers of students' career preferences.

To illustrate, we see that individuals with a strong taste for science have a clear preference for academia over established firms because they tend to both find R&D in established firms less attractive and research in academia more attractive. Thus, one could say they are both "pulled" into academia and "pushed away" from industry. On the other hand, we observe that individuals who are concerned about access to resources, in particular, access to cutting-edge technologies and equipment, have a preference for careers in established firms over academia primarily because they find established firms more attractive, not because they find academia particularly unattractive. Similarly, we see that individuals who care strongly about job security are much less likely to prefer startups over academia primarily because they find startups very unattractive, not because they would find academia particularly attractive.

5. Summary and discussion

Academically trained science and engineering PhDs play important roles in both industry and academia, yet little is known regarding how graduating PhDs select into these different employment sectors. Systematic selection effects along dimensions such as PhDs' "taste for science" or prior performance may have important implications for research on innovation in industry and academia, as well as for research on knowledge flows between the two sectors.

To learn more about the career choices of science and engineering PhDs, we surveyed over 400 PhD students at three major U.S. research universities. In the first part of our empirical analysis, we provide descriptive data on students' expectations regarding several key job attributes associated with employment in established firms, startups, and academia, on students' preferences for those job attributes, and on students' career preferences. Our respondents report very different expectations regarding careers in industry and academia; while academia is thought to have a clear advantage with respect to job attributes such as freedom to choose projects and ability to collaborate across organizational boundaries, industry is thought to offer higher salaries and more resources. These perceived differences between industry and academia are not smaller in the life sciences than in other fields, despite the recent notion of "convergence" between academic and industrial research in the life sciences (Vallas and Kleinman, 2008).

In the second part of our empirical analysis, we examine the factors associated with students' preferences for careers in industry and academia. Using two complementary econometric techniques, we find that students' career preferences are strongly predicted by their preferences for various job attributes. More precisely, we find that students with a strong taste for science, in particular, a strong preference for freedom to choose research projects, the ability to publish, and the desire to conduct basic research, strongly prefer academic careers over careers in industry. On the other hand, individuals concerned with salary, access to resources, and the desire to conduct downstream research and development are more likely to prefer careers in established firms over a career in academia. Individuals who value responsibility are more likely to prefer employment in startups over employment in academia, while those concerned with job security are significantly less likely to prefer a career in startups. While patents are not associated with career preferences, publications predict a preference for academia.

Our results suggest several important implications. First, our findings highlight the importance of considering individual differences in scientists' preferences and professional orientation generally and raise the possibility that industrial scientists may have a significantly weaker "taste for science" than scientists working in academia. While our findings do not contradict prior work that has shown that industrial scientists have a taste for science (Stern, 2004), they suggest that it is important to consider whether that taste is weak or strong. While it may be relatively strong when compared to firm employees that did not go through graduate training, it may be weak compared to PhDs who intend to pursue an academic career. A consideration of the *strength* of a taste for science may provide new insights into scientists' research activities. For example, it raises the question whether observed lower levels of publishing and other academic activities in industry are solely the result of constraints imposed by firms (Stern, 2004; Aghion et al., 2008) or if they are also a function of industrial scientists' lower desire to engage in such activities. In the latter case, relaxing constraints imposed by firms (e.g., as part of an "open innovation" strategy) may not necessarily bear fruit. In fact, the research by Henderson and Cockburn (1994) suggests that firms may need to provide explicit incentives to their employees to engage with the broader scientific community and cannot rely on scientists' innate "taste for science" alone. Our findings, as well as other recent work suggesting that scientists' preferences play an important role in innovation, raise the more general question of the sources and determinants of students' preferences. To what extent are these preferences inherited? To what extent are they shaped by early educational experiences and by socio-economic variables? To what extent are PhD students socialized during their graduate training or gain a "taste for science" based on early research success? While our findings do not answer these questions, they highlight the importance of addressing these questions in future research.

[7] While we interpret publication counts primarily as a measure of performance, they may also proxy for the importance and individual assigns to publishing and perhaps a "taste for science" more generally. In that sense, the observed effect of publications on career choice would reinforce our finding that students with a stronger taste for science prefer the faculty career.

Second, our finding that students think of academia and industry as very different in terms of job attributes seems at odds with the notion of "convergence" between the two sectors and suggests two interesting avenues for future research. First, empirical work is needed to evaluate and quantify actual similarities and differences between the two sectors along a range of characteristics, using representative samples from the life sciences as well as other fields (for a recent example, see Sauermann and Stephan, 2009). Second, future work should examine the accuracy of students' expectations and identify any potential systematic biases that may lead to poor job choices. Good decisions require accurate information, and students may benefit from more actively collecting information about careers in industry as well as other "alternative" careers. While firms as well as professional associations increasingly try to provide such information to students, it is not clear how effective such attempts currently are.

For industrial employers seeking to hire high-potential PhDs, our results suggest that resource related factors are currently the key attraction, and this includes not only salaries, but especially resources for research. At the same time, students seem to have strong concerns about low levels of attributes that are typically associated with "academic science" including the ability to publish and share research and freedom regarding the choice of one's research topics. While these concerns may be overdrawn, they pose a dilemma for firms that actually want to attract students with a strong taste for science (Henderson, 1994; Cockburn and Henderson, 1998). Combined with our finding that students feel significant gaps in their information about the work environment in firms, this suggests that firms that offer a more academic environment should send stronger signals to PhD students, counteracting some of the stereotypes about employment in industry that seem to persist.

While our focus has been on students' choice to enter an industrial career, our results also provide insights for those concerned with students' decisions to pursue academic careers, including policy makers and academic administrators. In particular, there has been a concern that funding shortages and other challenges junior researchers face in academia may drive out students into other sectors, including industry. While we do not observe actual career transitions, our data lend some support to this notion; we find that firms are judged as much more favorable with respect to resource related factors, and students who value access to resources such as cutting-edge technology, but also funding and salary, are attracted to careers in industry. On the other hand, the traditional advantages of academia, most notably intellectual freedom, seem to have a strong appeal to students. Moreover, students with higher past performance are more likely to prefer an academic career. Thus, academia seems to remain an attractive career path to many students. However, our results also suggest that further increases in the resource advantages of industrial firms and potential reductions in researchers' freedom in academia may significantly decrease the relative attractiveness of academic careers.

Our study is not without limitations. First, our study does not consider dynamic effects, such as the extent to which preferences for job attributes and career aspirations may change over the course of students' graduate education. Such dynamic effects could introduce complex interactions between preferences for job attributes and career aspirations, making causal statements difficult. In particular, some students may determine early in their PhD program that they prefer one career over the other and those students' preferences for job attributes such as independence and publishing may further change to reflect those career goals. While it would be desirable to clearly identify causal relationships between preferences for job attributes and career aspirations, even the mere correlation between these variables may have important implications because it provides insights into the characteristics and preferences of those scientists who may ultimately seek employment in industry.

Second, we observe only students' career preferences but not which career paths they eventually take. Career preferences and ultimate employment patterns may differ, however, because final outcomes are determined not just by self-selection of job candidates but also by employers' choice of particular candidates. While the employer side should matter less if students decide not even to apply for certain types of positions, a general shortage of positions in academia may ultimately "force" some students into the industrial sector even if they have a strong preference for academia. Such "forced" entry into industry may raise the average "taste for science" in industry, but it should also raise the average taste for science in academia (only "hardcore" academics persist in their quest to obtain a faculty position), with ambiguous effects on the industry–academia difference in the taste for science. More generally, however, future work is needed on employer–employee matching along multiple dimensions in the particular context of science. Such work should examine the relative importance of students' decisions versus those of employers in determining final career outcomes. Moreover, conceptualizing matching as occurring along multiple dimensions (e.g., pay, publishing opportunities, and availability of resources) also highlights the potential for imperfect matching, e.g., if students over-emphasize certain job attributes and ignore others that are less salient but turn out to be important in the long term (Sauermann, 2005). Future research on potential imperfections in the matching process may suggest important implications for students as well as potential employers. We hope that our work on the employee side provides a useful starting point for more comprehensive studies of science careers as outcomes of two-sided matching processes.

Despite its limitations, our study provides novel insights into students' career decisions and suggests that PhD students' preferences for factors such as independence, publishing, and the ability to collaborate with others, as well as for access to resources strongly predict whether students prefer a career in industry or a career in academia. This, in turn, highlights the importance of recognizing that scientists' "taste for science" and preferences more generally are likely to differ across individuals as well as between sectors. A conceptualization of scientists' preferences as a matter of degree should help future work seeking to examine more explicitly how scientists' preferences relate to research activities and outcomes in industry as well as in academia.

Acknowledgements

We acknowledge valuable comments from Jonathon Cummings, Jason Doherty, Erika Färnstrand Damsgaard, Maryann Feldman, Mary Fox, Dietmar Harhoff, Mary Napier, Paula Stephan, Long Vo and Wei Zhang. We also thank two anonymous reviewers and *Research Policy* editor Lee Fleming for helpful comments. Henry Sauermann acknowledges support from the Ewing Marion Kauffman Foundation.

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