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The declining interest in an academic career

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Abstract

There is increasing evidence that science & engineering PhD students lose interest in an academic career over the course of graduate training. It is not clear, however, whether this decline reflects students being discouraged from pursuing an academic career by the challenges of obtaining a faculty job or whether it reflects more fundamental changes in students' career goals for reasons other than the academic labor market. We examine this question using a longitudinal survey that follows a cohort of PhD students from 39 U.S. research universities over the course of graduate training to document changes in career preferences and to explore potential drivers of such changes. We report two main results. First, although the vast majority of students start the PhD interested in an academic research career, over time 55% of all students remain interested while 25% lose interest entirely. In addition, 15% of all students were never interested in an academic career during their PhD program, while 5% become more interested. Thus, the declining interest in an academic career is not a general phenomenon across all PhD students, but rather reflects a divergence between those students who remain highly interested in an academic career and other students who are no longer interested in one. Second, we show that the decline we observe is not driven by expectations of academic job availability, nor by related factors such as postdoctoral requirements or the availability of research funding. Instead, the decline appears partly due to the misalignment between students' changing preferences for specific job attributes on the one hand, and the nature of the academic research career itself on the other. Changes in students' perceptions of their own research ability also play a role, while publications do not. We discuss implications for scientific labor markets, PhD career development programs, and science policy.

Introduction

The number of science and engineering PhD degrees awarded in the U.S. has increased significantly over the last two decades (Fig 1). At the same time, the share of graduates holding tenure-track academic positions has declined, with the majority of science and engineering PhDs eventually taking positions outside of academia [1]. These trends have given rise to concerns that imbalances between the increasing supply of graduates and the limited number of

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available faculty positions may force many PhDs away from careers in academia [1–3]. On the other hand, recent research shows that many PhDs prefer non-academic careers upon graduation [4, 5], suggesting that labor market imbalances may not be as large as feared. However, it remains unknown whether the declining interest in an academic career is driven primarily by limited faculty job availability or whether it might also reflect substantive changes in career preferences irrespective of labor market conditions.

Using unique panel data from a survey of U.S. PhD students in science and engineering, this paper investigates how and why academic career preferences change over time during graduate training. Unlike prior studies that compare cohorts of students in the cross-section [4, 5], we observe the same PhD students first early in their program and then again three years later, allowing us to distinguish between students who remain interested in an academic career over time and those who lose interest. Moreover, we employ a unique measure that captures students' career preferences independent from their labor market expectations, thus disentangling their "true" preference for an academic career from how difficult they think it will be to get an academic position. This measure allows us to provide clearer insights into students' career preferences and the supply side of STEM labor markets.

We report two main results. First, the decline in Ph.D. students' interest in an academic career is not a general phenomenon across all students, but rather is a significant divergence between students who remain highly interested in an academic career and others who lose interest in an academic career entirely. Second, we show that the decline we observe is driven not by expectations about the academic job market, but instead partly reflects changes in

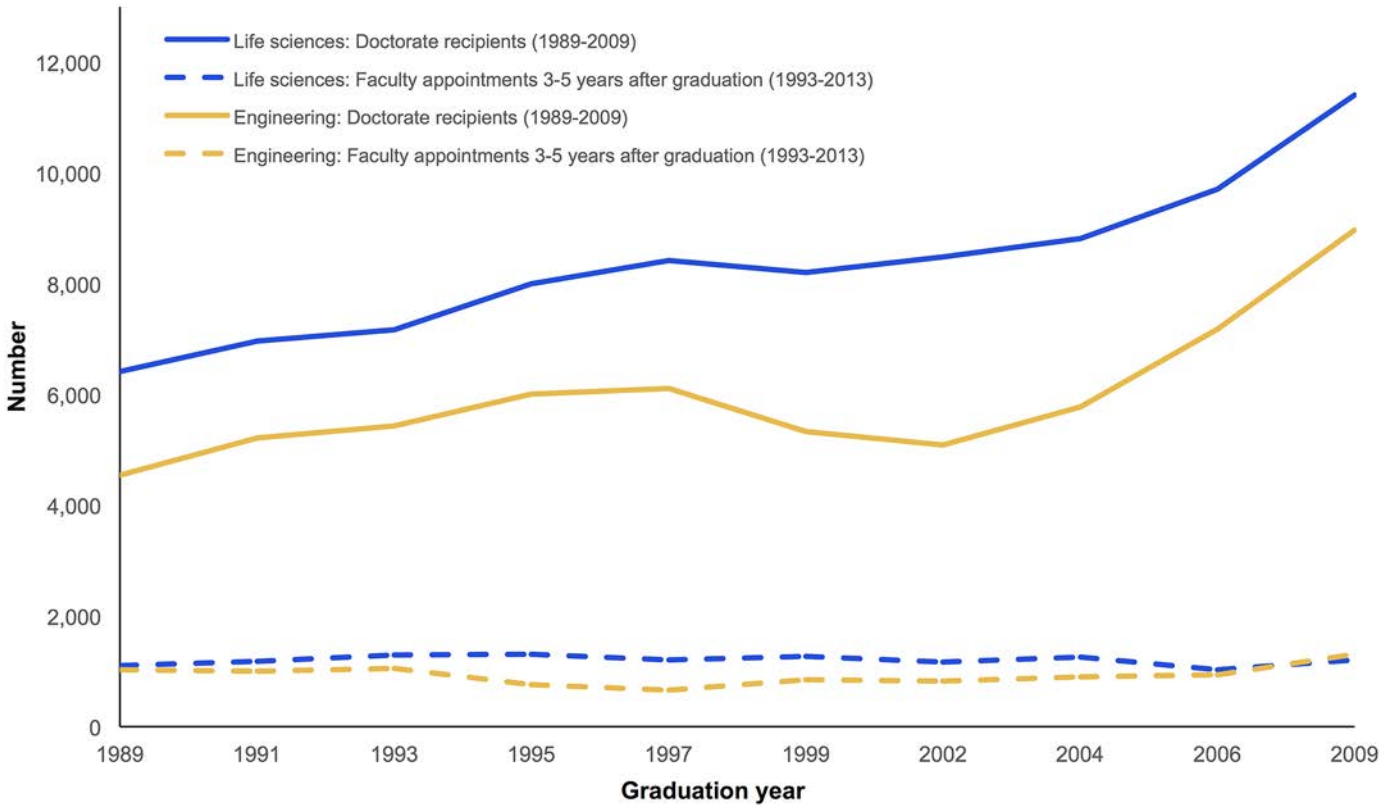

Fig 1. U.S. trends in life science & engineering doctorates and faculty appointments. Number of doctorate recipients and number of tenure-track faculty appointments 3–5 years after graduation (Data Source: NSF Survey of Doctorate Recipients; number of tenure-track faculty appointments calculated by the authors).

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students' preferences for specific aspects of the faculty career, such as performing basic research and having freedom to choose research projects.

Although labor market conditions almost certainly prevent some doctoral students who remain interested in an academic career from obtaining a faculty position, our findings suggest that many students turn away from academia for reasons other than the lack of faculty positions. As such, discussions of PhD students' career goals and career pathways should consider a broad set of market and non-market factors. Our findings also provide urgency to the National Academies' recent call for better data on students' career preferences [6], and we present a measure that may be useful in such data collection efforts. Our results suggest the need for greater flexibility in graduate programs and may help faculty advisors, program administrators, and policy makers to improve STEM training experiences. Our findings also have important implications for research on STEM labor markets, universities' efforts to improve graduate education, and federal efforts to track and manage the STEM labor supply.

Background

Before we examine changes in students' academic interests empirically, it is useful to consider briefly some of the potential reasons for such changes. While this discussion is far from exhaustive, it is meant to introduce some of the market and non-market factors that may be at play. To begin, a common explanation is that PhD students are discouraged from pursuing an academic career because they learn about the limited number of faculty openings and the low likelihood of obtaining a tenure-track position [2, 7, 8]. As such, PhD students' "true" preference for an academic career may not have changed, but their expectations of being able to obtain a faculty position have. To the extent that stated career preferences are influenced by labor market expectations, they would understate the share of graduates who aspire to an academic career.

Students may also lose interest in an academic career for reasons unrelated to labor market conditions. For example, during the course of the PhD program, students may gain deeper insight into the life of a faculty member and realize that this career is not what they expected [9, 10]. Although common stereotypes highlight attractive features such as autonomy, the opportunity to do curiosity-driven research, and inspiring social interactions in an invisible college of peers, the faculty career is not without challenges. For example, funding conditions have deteriorated in many fields and junior faculty in particular face significant difficulties in securing grants to fund their work [7]. As such, faculty members spend significant amounts of time on acquiring and administering resources, which detracts from the time they can spend on research [11]. Moreover, both funding agencies and tenure committees place great emphasis on quantitative measures of research output, increasing the pressure to generate publications and sometimes detracting from curiosity driven discovery [7]. Students may also realize that for faculty members, "doing research" does not always mean hands-on investigation but often involves administrative tasks in managing a lab and conveying research to external audiences [12, 13]. Finally, while autonomy is often highlighted as one of the key benefits of being an academic, success in such an unstructured occupation requires the ability to balance competing demands from teaching, research, and administration. It also requires the willingness to take initiative, the ability to make tough choices regarding which projects to pursue, and good sense for when to persist or give up on a project that seems likely to fail [12, 14].

Although these and other challenges associated with being a faculty member have been highlighted in prior scholarly work and policy discussions, many applicants do not think explicitly about career options when enrolling in a PhD program [15, 16]. Moreover, it is unlikely that the various facets of the faculty career can be understood simply by reading about

them: Students are likely to realize what it means to be a faculty member primarily through extended exposure to mentors and peers during graduate training, and through their own involvement in research and teaching [10, 17]. As such, students may gradually re-evaluate the attractiveness of the faculty career over the course of the PhD program or may realize that their own interests are not a fit for this career path. Upon experiencing the highly competitive nature of academia and gaining a better understanding of their own abilities, students may also re-evaluate their chances of success, or the time and effort they would have to commit in order to succeed. Of course, training experiences are not uniform [17], and while some students may realize that the faculty career is not the best fit for them, others may remain highly interested and some may even increase their commitment to this career path.

Materials and methods

We examine changes in PhD students' career interests using a longitudinal survey that followed 854 students over the course of their PhD training in the life sciences (36%), chemistry (12%), physics (18%), engineering (24%), and computer science (10%). Unlike prior studies that compare cohorts of students in the cross-section [4, 5], our longitudinal approach allows us to directly assess changes for a given person and to distinguish between PhD students who remain interested in an academic career and those who lose interest during graduate training. To obtain the initial sample, we identified 39 tier-one U.S. research universities with doctoral programs in science and engineering fields by consulting the National Science Foundation's reports on earned doctorates [18]. Our selection of universities was based primarily on program size while also ensuring variation in private/public status and geographic region. The 39 universities in our sample produced roughly 40% of the graduating PhDs in science and engineering fields in 2009 [2, 7, 8]. The questionnaire was validated by inviting a select sample of PhD students at the investigators' universities to complete the survey followed by an exit interview to probe students' understanding of key questions and to solicit feedback on the instrument. The respective Institutional Review Boards at Cornell University and the Georgia Institute of Technology approved this survey. Participation in the survey was voluntary and subjects consented by completing the survey.

Respondents were contacted through email addresses obtained from university department and research lab websites and invited to participate in an online survey regarding their PhD experience and career goals. The first survey was administered in February 2010 to nearly 30,000 PhD students and postdocs at various stages of their training, with a response rate of 30%. As part of the 2010 survey, we asked respondents to provide us with a permanent email address (e.g., a Gmail account), which was used to contact respondents in February 2013 with a follow-up questionnaire. If respondents did not provide an email in the 2010 survey (20% of respondents), we used the original university email address from the 2010 survey. In this study we focus on the subset of 854 respondents who were first or second year PhD students in 2010 and who responded as fourth or fifth year students in 2013, with a 40% response rate for the second survey.

To examine potential nonresponse bias in this sample, we regressed response status in 2013 on key characteristics from the 2010 survey. We find that the likelihood of a response to the follow up was higher for respondents who were US citizens and who were in the second (vs. first) year of their PhD studies. Controlling for these factors, we do not find significant differences with respect to career interests. We include the relevant variables as controls in our regression analyses, which are described in detail in the Results section below. S1 Table reports summary statistics. The specific survey questions used in this study are reported in S1 Text.

Results

Our empirical analysis involves three parts. We first document changes in career preferences over time using longitudinal data and explore whether changes are a general phenomenon or are limited to certain parts of the population. We then examine whether the changes we observe may be driven by students' expectations regarding labor market conditions using non-parametric methods and also explore other potential reasons for changes in career preferences including changes in interests in different types of tasks or job attributes and changes in subjective ability. Finally, we present a series of regression analyses that allow us to examine the potential drivers of changes in career preferences jointly while controlling for demographic characteristics and other factors.

Assessing changes in academic career interests

We rely on direct measures of career interests rather than interpreting observed career transitions that may confound both preferences and labor market constraints [19, 20]. We asked respondents at both points in time: "Putting job availability aside, how attractive or unattractive do you personally find each of the following careers?" Although the survey asked about a range of research and non-research careers inside and outside academia, this paper focuses on students' interest in "university faculty with an emphasis on research or development" (*academic career*). Respondents rated this career independently from other careers using a 5-point scale ranging from "extremely unattractive" (1) to "neither attractive nor unattractive" (3) to "extremely attractive" (5). By explicitly asking respondents to disregard current labor market conditions, our measure attempts to capture PhD students' interest in an academic career independent of factors that may hinder their ability to obtain an academic career, such as a limited number of available faculty positions.

We dichotomized the scale to distinguish between PhD students who are interested in an academic research career (i.e., ratings of "extremely attractive" or "attractive") and those who are not (i.e., ratings of "neither attractive nor unattractive", "unattractive", or "extremely unattractive") early in the PhD program (2010), as illustrated in Fig 2. We similarly coded students' interest in an academic research career three years later (2013) when they were in an advanced stage of their PhD and near graduation [21]. To construct our change measure, we then code students who are interested in an academic research career in both periods as remaining interested and students who were interested early in the PhD but are no longer interested later in the program as losing interest in an academic career.

Although the preponderance of all PhD students (80%) started the program with an interest in an academic career, three years later just over half (55%) remain interested in an academic career and one-quarter (25%) lose interest. Put differently, nearly one-third of doctoral students who started the PhD program interested in an academic research career lost interest in that career by the time they neared graduation. Moreover, PhD students who lose interest in an academic career show a substantial decline in their ratings on the original 5-point attractiveness scale, dropping from a mean of 4.3 in 2010 to 2.2 in 2013, with two-thirds of them now reporting that an academic career is either "unattractive" or "extremely unattractive". As we would expect given the construction of our measure, the average attractiveness score does not change significantly among PhD students who remained interested in an academic career (mean of 4.5 in 2010 and 4.4 in 2013). Thus, the declining interest in an academic career is not a general phenomenon, but rather reflects a significant divergence between PhDs who remain interested in an academic career and others who lose interest in academia entirely.

Approximately 20% of all PhD students started the program uninterested in an academic career, and over time 15% remain uninterested and 5% gain interest. Table 1 reports the

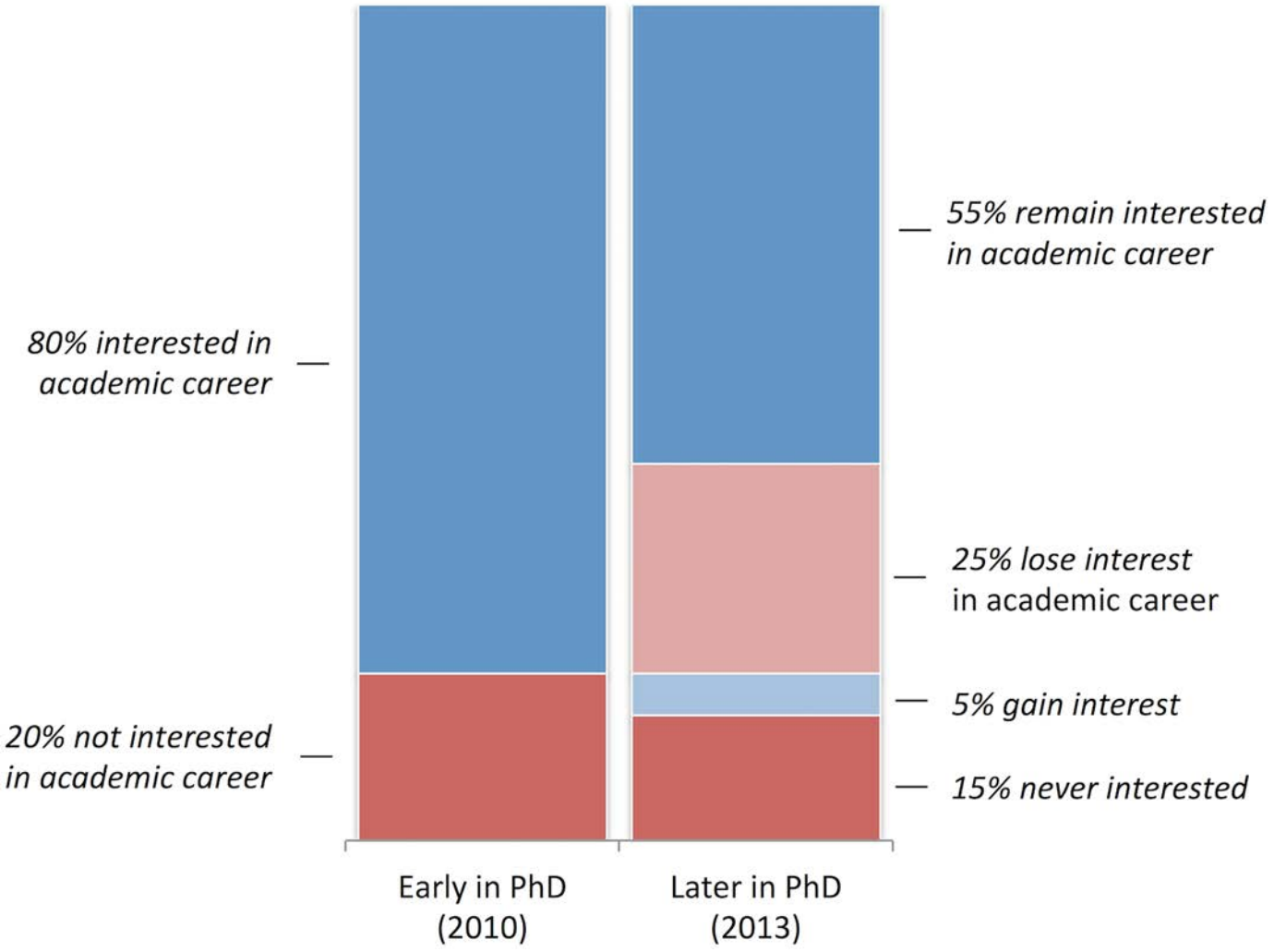

Fig 2. Change in academic career interests during the PhD program.

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change in academic career interests across broad fields of science and engineering. Due to limited sample size, our main analysis uses the pooled sample, with controls for 36 subfields in regression models. We report auxiliary analyses for selected fields towards the end of the paper.

Table 1. Academic career interests by field. Levels early in the PhD (2010) and changes from 2010 to 2013.

Field of Study	Obs.	*2010*	*Change from 2010 to 2013*			
		Academic career interest early in PhD	Remain interested	Lose interest	Gain interest	Never interested
Life sciences	313	83%	59%	25%	4%	12%
Chemistry	107	60%	30%	30%	8%	32%
Physics	154	92%	66%	26%	4%	5%
Engineering	193	76%	52%	24%	6%	18%
Computer science	87	80%	65%	15%	8%	12%
All Fields	**854**	**80%**	**55%**	**25%**	**5%**	**15%**

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Table 2. Academic career interests by gender and nationality.

	Obs.	*2010*	*Change from 2010 to 2013*			
		Academic career interest early in PhD	Remain interested	Lose interest	Gain interest	Never interested
Gender						
Men	500	83%	59%	24%	5%	12%
Women	345	75%	50%	25%	6%	19%
Nationality						
U.S. citizens	626	79%	51%	27%	6%	16%
Non-U.S. citizens	219	84%	68%	16%	5%	11%

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Table 2 examines potential differences by demographic characteristics. A greater share of men start the PhD with an interest in an academic career relative to women (83% vs. 75%), and this difference is highly significant (t-statistic -2.99, p-value 0.003). Moreover, this difference persists over time with 59% of men remaining interested in an academic career compared to 50% of women. Although levels of career interests differ by gender, similar shares of men and women report a decline in their interest in an academic career over time (24% and 25%, respectively); 19% of women were not interested in academic research in either time period compared to 12% of men. These results are broadly consistent with prior cross-sectional evidence [22].

The difference in the share of U.S. citizens (79%) and foreign PhD students (84%) interested in an academic career at the beginning of the PhD is only marginally significant (t-statistic 1.73, p-value 0.08). However, 27% of U.S. citizens lose interest in an academic career compared to only 16% of foreign PhD students. As they near graduation, 51% of U.S. citizens remain interested in an academic career compared to 68% of foreign students, and this difference is highly significant (t-statistic 4.38, p-value 0.001). Although these patterns are intriguing, a detailed examination of these differences is beyond the scope of this paper.

Non-parametric analyses of potential reasons for changes in academic interests

We now examine whether the changes in academic career interests observed above are associated with students' expectations of labor market conditions using nonparametric methods. We also examine the extent to which the declining interest in an academic career is associated with changes in preferences for work activities and job attributes, as well as proxies for students' ability. (See S1 Table for a comprehensive list of variables).

Labor market expectations. As noted in the description of the measure of career interests, the survey question was designed to capture career preferences independent from labor market conditions. To validate this important aspect of our approach, we now examine the relationships between academic career interests and three factors related to the academic labor market as illustrated in Fig 3 and summarized in Tables 3 & 4.

First, we asked respondents both in early in their PhD (2010) and again three years later at an advanced stage of their PhD (2013): "What do you think is the probability that a PhD in your field can find the following positions after graduation (and any potential postdocs)", where the listed positions included "university faculty with an emphasis on research or development" as well as "established firm job with an emphasis on research or development." Respondents reported expected probabilities on a scale ranging from 0–100%. Panel A in Fig 3 shows that early in the program both groups expect that nearly half of PhD graduates in their field can obtain a faculty position at some point in their career. Over time these expectations

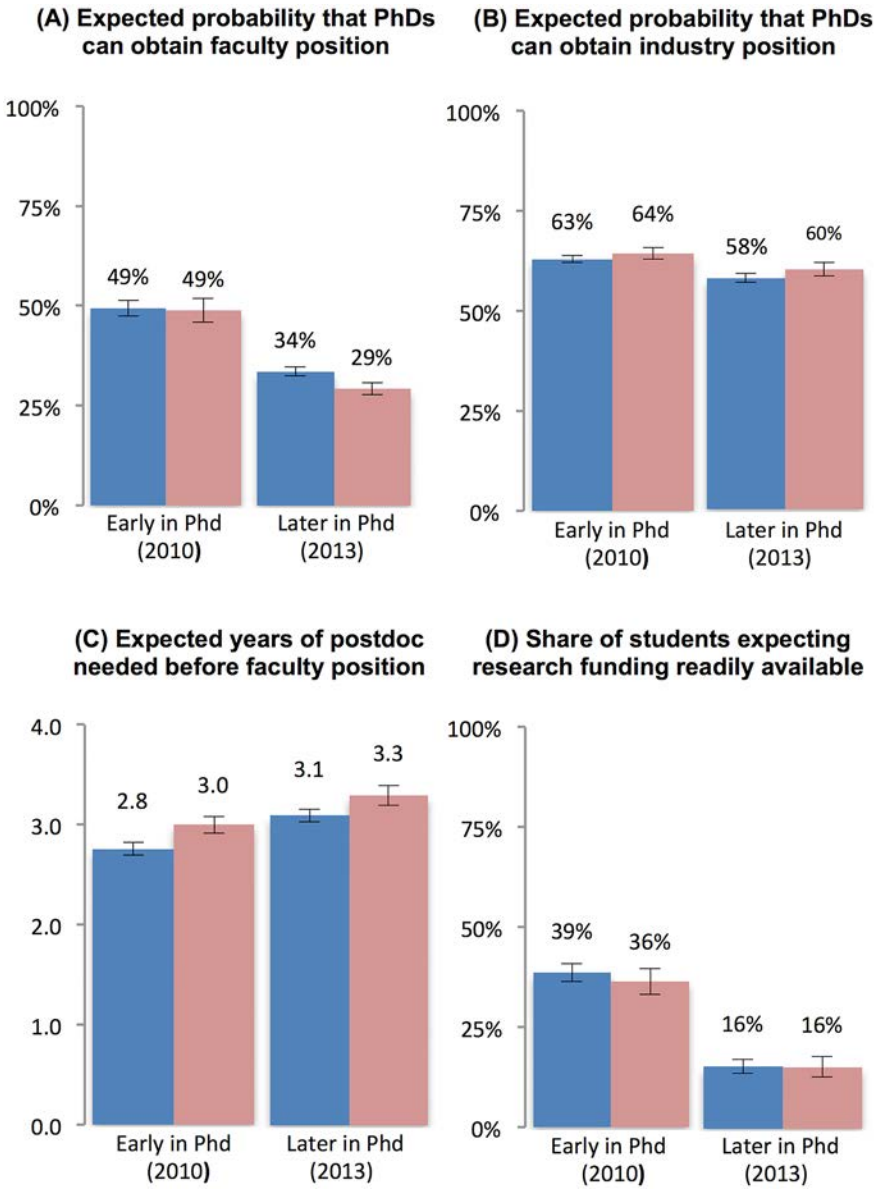

Fig 3. Changes in expectations of academic labor market conditions. Individuals who remain interested in an academic career drawn in dark blue and those who lose interest in an academic career in light red; (A) expected probability that a PhD in their field can obtain a faculty position after graduation; (B) expected probability that a PhD in their field can obtain an industrial R&D position after graduation; (C) expected number of years of postdoctoral research needed to obtain a faculty position; (D) expected availability of funding for academic research.

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decrease significantly for all students, irrespective of whether they remain interested in an academic career or lose interest. Although students who lose interest have significantly lower expectations later in the PhD program regarding the probability of obtaining a faculty job than those who remain interested (34% vs. 29%, p = 0.02), the change in expectations is similar in magnitude and not statistically different between the two groups (Table 3, -20% change vs. -16% change, p = 0.10). Panel B in Fig 3 shows that students who remain interested in an

Table 3. Means of key variables by stage in the PhD program.

	Early in PhD (2010)				*Later in PhD (2013)*				*Change during PhD (2010 to 2013)*			
	Remain interested	Lose interest	t-test	p-value	Remain interested	Lose interest	t-test	p-value	Remain interested	Lose interest	t-test	p-value
Labor market expectations												
Expected probability of faculty position	49%	49%	0.29	0.77	34%	29%	2.31	0.02	-16%	-20%	1.66	0.10
Expected probability of industrial R&D position	63%	64%	0.82	0.41	58%	60%	1.13	0.26	-4%	-5%	0.41	0.68
Years of postdoc required for faculty position	2.76	2.97	1.87	0.06	3.11	3.28	1.54	0.12	0.31	0.30	-0.15	0.88
Availability of research funding	38%	36%	0.56	0.58	15%	15%	0.09	0.93	-23%	-21%	-0.43	0.67
Work preferences												
Interest in basic research	92%	87%	2.49	0.01	92%	53%	13.93	0.00	0%	-33%	9.55	0.00
Interest in applied research	93%	94%	-0.29	0.77	93%	84%	3.58	0.00	0%	-10%	3.25	0.00
Interest in commercialization	42%	44%	-0.38	0.70	38%	55%	-4.19	0.00	-4%	11%	-3.40	0.00
Importance of salary	79%	78%	0.13	0.89	80%	80%	0.08	0.94	2%	2%	-0.05	0.96
Importance of freedom	92%	86%	2.51	0.01	88%	61%	8.46	0.00	-4%	-25%	5.72	0.00
Ability												
Self-perceived ability	6.39	6.00	3.21	0.00	6.98	5.99	8.15	0.00	0.59	-0.01	4.21	0.00
Number of publications	0.96	0.80	1.37	0.17	2.72	2.29	2.32	0.02	1.87	1.66	1.33	0.18

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academic career and those who lose interest report similar expected probabilities of obtaining an industrial R&D position, and this probability decreases only slightly over time.

Second, a lower availability of tenure-track positions is likely reflected in a longer duration of postdoctoral appointments before graduates can find a tenure-track position [3, 6, 15]. Accordingly, we asked PhDs "How many years of postdoc experience do you think are required on average to obtain a university faculty position with an emphasis on research or development in your field?" Respondents answered on a multiple-choice scale that ranged from 0 years (i.e., no postdoc required) to 5 or more years. Panel C in Fig 3 shows that students' expectations regarding the duration of postdoctoral training required increased slightly over the course of the PhD program, consistent with an increasing awareness of labor market challenges. However, we find no significant differences in the changes in expectations between

Table 4. Means of key variables by change in academic career interests.

	Remain interested				*Lose interest*			
	Early in PhD (2010)	Later in PhD (2013)	t-test	p-value	Early in PhD (2010)	Later in PhD (2013)	t-test	p-value
Labor market expectations								
Expected probability of faculty position	49%	34%	12.46	0.00	49%	29%	10.42	0.00
Expected probability of industrial R&D position	63%	58%	4.43	0.00	64%	60%	2.55	0.01
Years of postdoc required for faculty position	2.76	3.11	-4.59	0.00	2.97	3.28	-2.76	0.01
Availability of research funding	38%	15%	9.01	0.00	36%	15%	5.29	0.00
Work preferences								
Interest in basic research	92%	92%	0.42	0.67	87%	53%	8.68	0.00
Interest in applied research	93%	93%	0.14	0.89	94%	84%	3.76	0.00
Interest in commercialization	42%	38%	1.64	0.10	44%	55%	-2.88	0.00
Importance of salary	79%	80%	-0.78	0.43	78%	80%	-0.54	0.59
Importance of freedom	92%	88%	2.30	0.02	86%	61%	6.64	0.00
Ability								
Self-perceived ability	6.39	6.98	-7.72	0.00	6.00	5.99	-0.06	0.95
Number of publications	0.96	2.72	-17.91	0.00	0.80	2.29	-10.81	0.00

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students who lose interest in faculty careers and those who remain interested (increase of 0.30 and 0.31 years, respectively, Table 3).

Finally, we consider whether increasing awareness of the challenges of obtaining research funding might explain the declining interest in an academic career. We asked students in both periods "To what extent do you think research funding is available to faculty members at a research university?" using a 5-point scale ranging from 1 ("extremely low") to 5 ("extremely high"). We dichotomized responses to distinguish students who believed that research funding was readily available ("extremely high" and "high") and those who did not. Panel D in Fig 3 shows that the share of PhD students with expectations that research funding is readily available declined significantly for both groups over the course of the PhD program, and the decline is not significantly larger among student who lose interest in an academic research career (Table 3).

Taken together, these results show that while PhD students adjust their expectations of labor market conditions over time, an increasing awareness of labor market challenges is shared by students who remain interested in an academic research career and those who lose interest. As such, differences in the degree to which labor market expectations changed are unlikely to explain why some students lose interest in the academic career while others remain highly interested. Note that even if changes in labor market expectations are similar for both groups, it could be that these changes had a larger impact on one group of students than the other. We explore this possibility below but find no evidence that this was the case.

Preferences for work activities and job attributes. We now turn to potential non-market reasons for changes in students' academic interests. We first explore the possibility that students may lose interest in the faculty career because of changes in their preferences for different types of work activities such as basic research or for job attributes such as freedom and pay. Such preferences for work activities and job attributes have been shown to predict career choice [23, 24], but we are not aware of studies using a dynamic perspective to examine changes in these preferences and changes in career interests.

We asked in both waves of the survey: "When thinking about the future, how interesting would you find the following kinds of work?", using a 5-point scale ranging from "extremely uninteresting" to "extremely interesting." Work activities included basic research ("research that contributes fundamental insights or theories"), applied research ("research that creates knowledge to solve practical problems") and commercialization ("commercializing research results into products or services"). To measure preferences for job attributes students were asked "When thinking about an ideal job, how important is each of the following factors to you?", using a 5-point scale ranging from "not at all important" to "extremely important." The listed factors include "financial income (e.g., salary, bonus, etc.)" and "freedom to choose research projects".

To simplify comparisons, we dichotomize these measures and distinguish between students who report strong preferences for the different work activities ("interesting" or "extremely interesting") or job attributes ("important" or "extremely important") and those who report indifferent or weak preferences. Fig 4 shows that early in the PhD program the vast majority of PhDs have a strong preference for basic and applied research, as well as for freedom in choosing research projects. PhD students who remained interested in an academic career later in the PhD changed little over time with respect to these preferences. Among students who lost interest, however, the share with strong preferences for basic research, applied research, and freedom decreased significantly (Table 3), while the share with a strong preference for commercialization increased. There is no significant difference between groups and no significant change over time in preferences for financial income (Table 3).

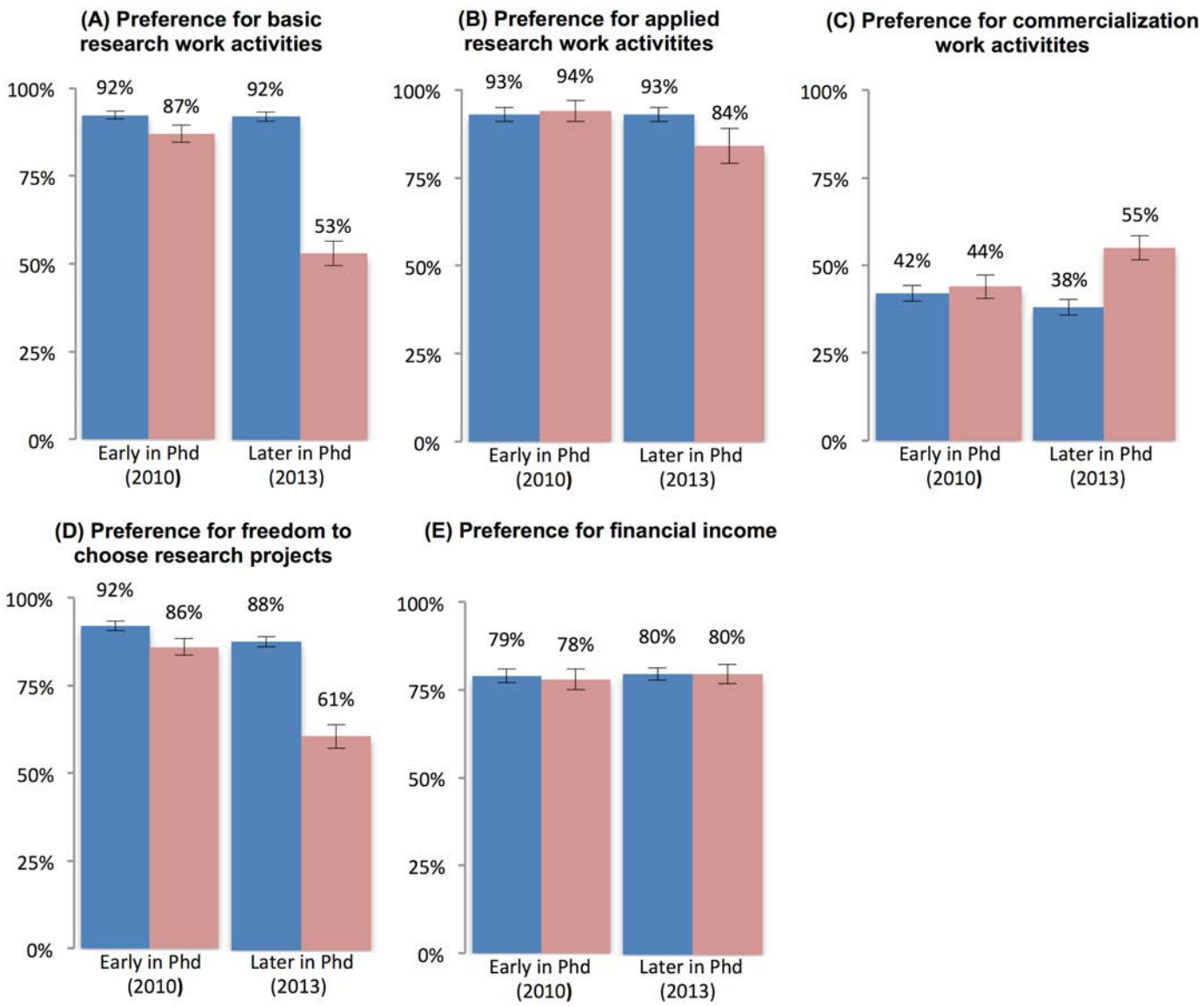

Fig 4. Changes in preferences for work activities and job attributes. Individuals who remain interested in an academic career are drawn in dark blue and those who lose interest in an academic career in light red; (A) preference for engaging in basic research work activities; (B) preference for engaging in applied research work activities; (C) preference for engaging in commercialization work activities; (D) preference for freedom in choosing work projects; (E) preference for financial income.

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Taken together, our observations are consistent with the notion that preferences for work activities and job attributes shape students' career interests [23, 25] and suggest that the decreased interest in a faculty career partly reflects changes in students' preferences for certain aspects of this career path such as the focus on basic research. We note, however, that these data do not allow for a clear identification of causality. While the longitudinal nature of the analysis reduces concerns about omitted variables (e.g., a comparison of changes eliminates the influence of fixed individual characteristics), we cannot rule out reverse causality, i.e., that changes in career interests may lead to changes in preferences for work activities and job attributes.

Ability. Over the course of their graduate studies, PhD students are likely to also gain a better understanding of their own ability. Students who realize that they are not at the top of the ability distribution or who are less successful in developing publishable research than others may understand that it will be difficult to succeed in the highly competitive academic research enterprise, even if they were able to secure a faculty position. To examine whether learning about ability may explain changes in career preferences, we use two different proxies for ability. First, we asked respondents in both waves of the survey: "How would you rate your research ability relative to your peers in your area of specialization?", using a sliding scale ranging from 0 (among the least skilled) to 5 (average) to 10 (among the most skilled). This measure has a mean of 6.17 early in the PhD and 6.64 later in the PhD, suggesting that students feel that their (relative) ability increases slightly with time in the program. To obtain a more objective proxy for ability, we also asked respondents to indicate how many published or accepted articles in peer-reviewed journals listed them as authors. As expected, this measure increases sharply over the course of the PhD training, rising from a mean of 0.87 publications early in the PhD to 2.52 publications three years later. Subjective and objective measures are significantly correlated in both time periods, although these correlations are only of moderate size (0.18 in 2010 and 0.21 in 2013).

Fig 5 shows that students who remain interested in the faculty career start with higher levels of subjective ability (6.39 vs. 6.00, t-statistic = 3.21 p-value = 0.001, Table 3) and publications (0.96 vs. 0.80, t-statistic = 1.37 p-value = 0.170, Table 3) than those who lose interest. More importantly, subjective ability increases significantly among those who remain interested in academia (from 6.39 to 6.97; t-statistic = 7.72 p-value = 0.001, Table 4), while it remains unchanged among those who lose interest in academia (t-statistic = 0.06 p-value = 0.951, Table 4). Publication counts increases for both groups, but only slightly more for PhD students who remain interested in academia (increase by 1.7 publications) than for those who lose interest (increase by 1.5).

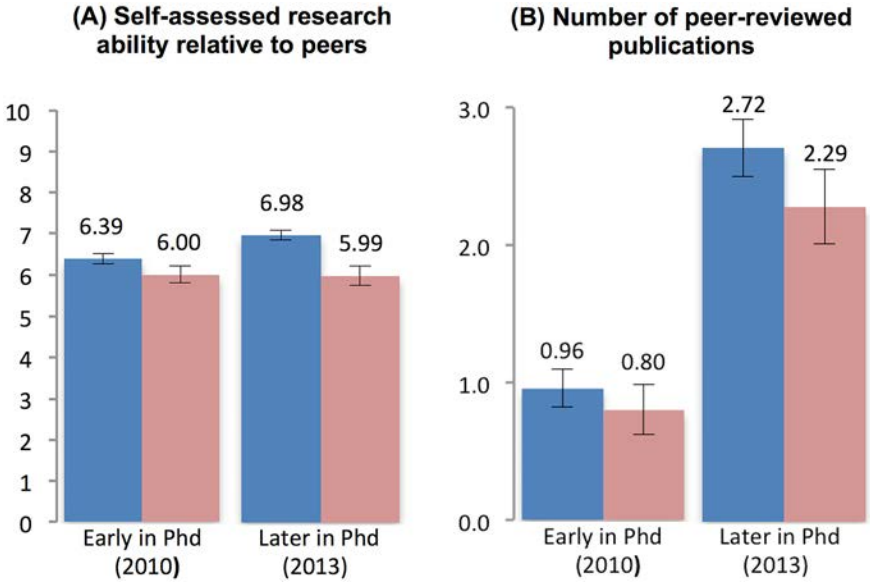

Fig 5. Changes in ability. Individuals who remain interested in an academic career are drawn in dark blue and those who lose interest in an academic career in light red; (A) self-assessed research ability relative to peers in their field: (B) number of academic articles published or accepted for publication.

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Taken together, we find evidence that changes in career interests may partly reflect changes in students' assessments of their own ability and performance. But again, the observed correlations do not imply causation. In particular, we cannot rule out that students who decide not to pursue a faculty position are less driven to publish their research. This concern is somewhat mitigated by the observation that publications also have considerable value when students seek non-academic jobs and that publishing decisions in academic labs are to a large extent driven by the strong career incentives of advisors [1, 26, 27].

Regression analyses

Main models. We now examine these relationships systematically through a series of regression analyses that allow us to examine more carefully two different issues. First, they allow us to correlate changes in career preferences with changes in independent variables such as labor market expectations or ability, similar to the approach used in the nonparametric analysis. Towards this end, we estimate a multinomial regression model that uses as the dependent variable a categorical variable distinguishing PhD students who remain interested in an academic career (base category of the dependent variable), PhD students who lose interest, PhD students who gain interest, and PhD students who were never interested in an academic career. Independent variables include changes in labor market expectations, preferences for job attributes, and ability, as well as a range of control variables such as field of study, the National Research Council ranking of the students' primary department [28], and demographic characteristics such as gender and citizenship (see S1 Table for key variables). The basic structure of this regression is:

$$\begin{aligned}\text{CHG\_ACAD\_CAREER}_i = {} & \beta_1 \text{CHG\_MARKET}_i + \beta_2 \text{CHG\_PREFS}_i + \beta_3 \text{CHG\_ABILITY}_i \\ & + \beta_4 \text{CHG\_CONTROLS}_i + \beta_5 \text{CONTROLS}_i + \varepsilon_I, \end{aligned} \quad (1)$$

where CHG_ACAD_CAREER_i is a categorical variable classifying respondent i by whether and how the interest in academic research has changed, CHG_MARKET_i is a vector of variables capturing changes in the respondent's market expectations, CHG_PREFS_i is a vector of variables capturing changes in preferences for work activities and job attributes, CHG_ABILITY_i is a vector of changes in proxies for ability, CHG_CONTROLS_i is a vector of changes in time-varying controls, and CONTROLS_i is a vector of time invariant controls. By using changes for both the dependent and key independent variables, this model also partly addresses concerns about otherwise unobserved time-invariant heterogeneity across individuals, including potential biases in survey response behavior.

Considering changes in independent variables as predictors of changes in the outcome of interest over time is based on the premise that levels of independent variables predict levels of outcomes at a given point in time. For example, if a decrease in students' interest in basic research between 2010 and 2013 explains a decrease in the attractiveness of a faculty career, then we would also expect that at a given point in time, students with a weaker interest in basic research report the faculty careers as less attractive. As such, we estimate a second set of regressions using cross-sectional data from each wave of the survey. In addition to showing which factors are correlated with academic career interests at a given point in time, these regressions allow us to examine whether key coefficients change between 2010 and 2013, e.g., whether the interest in basic research has become a more or less important predictor of the attractiveness of a faculty career. The basic structure of these regressions (estimated using ordered logit) is:

$$\text{ACAD\_CAREER}_{it} = \beta_1 \text{MARKET}_{it} + \beta_2 \text{PREFS}_{it} + \beta_3 \text{ABILITY}_{it} + \beta_4 \text{CONTROLS}_{it} + \varepsilon_I, \quad (2)$$

where $ACAD\_CAREER_{it}$ is the respondent's rating of interest in the faculty research career, and where the subscript t stands for either 2010 or 2013.

Taken together, the two sets of regressions provide insights into the degree to which the decline in academic career interests may be explained by changes in the levels of important predictor variables (e.g., labor market expectations, individual preferences or perceived ability), but also by changes in the role these variables play in shaping career interests at a given point in time (see [29]).

Table 5 presents multinomial regression coefficients as relative risk ratios such that coefficients >1 indicate a positive relationship, coefficients = 1 indicate no relationship, and coefficients <1 indicate a negative relationship. Model 1 includes only control variables. Model 2 adds measures of changes in labor market expectations, which are consistent our earlier non-parametric finding that changes in labor market expectations have no systematic relationship with changes in respondents' interest in the academic career. Also consistent with the non-parametric analysis, Model 3a shows that respondents whose interest in basic research has decreased are significantly more likely to lose interest in an academic career relative to remaining interested (the omitted category of the dependent variable). We also observe a marginally significant association between an increasing interest in commercialization activities and losing interest in an academic career (p-value = 0.075). Students whose preference for research freedom has decreased are also more likely to lose interest in an academic career, while respondents who feel that their research ability has increased are less like to lose interest [30]. Although our focus is on students who lose interest in academia rather than those who gain interest, Model 3b shows that PhD students who gain interest in an academic career also exhibit a significantly decreased interest in commercialization, an increased preference for research freedom and increased subjective ability, reinforcing the importance of these variables in explaining changes in academic career interests.

Models 1–4 in Table 6 use the two waves of the survey separately to provide insights into the relationships between predictors and the *levels* of academic career interest at a given point in time. Models 1 and 2 use data from 2010 and Models 2 and 4 use data from 2013. We use as dependent variable the original 5-point measures of the attractiveness of the faculty research career and estimate models using ordered logit regression. As noted earlier, the most interesting aspect of these regressions is that they allow us to compare the coefficients of independent variables between the two time periods. Focusing on variables that are significant in at least one of the models, we find that the coefficients of the interest in basic research and of the importance of freedom to choose research projects are remarkably similar in the two waves ($Chi^2(1) = 0.43$, $p = 0.51$ and $Chi^2(1) = 0.09$, $p = 0.76$, respectively). Although the coefficients of the interest in commercialization and of the importance of salary change from insignificant in 2010 to significant in 2013, the point estimates are quite similar and the coefficients are not significantly different between the two time periods ($Chi^2(1) = 0.62$, $p = 0.43$ and $Chi^2(1) = 3.07$, $p = 0.08$, respectively). The positive coefficient of subjective ability is significantly larger in 2013 than in 2010 (1.48 vs. 1.24; $Chi^2(1) = 4.81$, $p<0.05$).

We note that publications have no significant coefficients, and per the results in Table 5 changes in publications also did not have an effect. This may reflect that any effect of publications is mediated by students' self-perceived ability, which ultimately shapes students' career preferences. To examine this possibility, we re-estimated key models including publications but excluding subjective ability. We find no significant coefficient in the multinomial logit regressions or in the 2010 ordered logit regressions. However, publications are highly significant in the 2013 ordered logit (odds ratio 1.08, $p<0.01$). This finding suggests that it is primarily self-perceived ability that influences students' career interests, although objective measures

Table 5. Multinomial regressions predicting change in academic career interest (categorical DV).

Method	Multinomial logit								
Description	*Baseline*			*Labor market factors*			*Market & non-market factors*		
Dependent variable (relative to remain interested in an academic career)	Lose interest	Gain interest	Never interested	Lose interest	Gain interest	Never interested	Lose interest	Gain interest	Never interested
Model	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
Labor market expectations									
Chg. availability of faculty positions				0.55	1.23	1.57	0.53	1.55	1.38
				[0.27,1.11]	[0.39,3.91]	[0.61,4.06]	[0.23,1.24]	[0.46,5.21]	[0.53,3.60]
Chg. availability of industry positions				1.71	2.19	1.66	2.00	2.25	2.07
				[0.76,3.84]	[0.31,15.27]	[0.72,3.80]	[0.77,5.22]	[0.35,14.40]	[0.79,5.45]
Chg. number of years of postdoc				0.99	1.00	1.04	0.97	0.96	1.02
				[0.87,1.12]	[0.77,1.31]	[0.83,1.31]	[0.83,1.14]	[0.71,1.28]	[0.81,1.28]
Chg. availability of research funding				0.92	0.91	0.97	0.95	0.92	0.94
				[0.79,1.09]	[0.65,1.28]	[0.81,1.18]	[0.79,1.13]	[0.64,1.32]	[0.77,1.15]
Work preferences									
Chg. basic research work activities							0.47***	0.97	0.80
							[0.37,0.61]	[0.62,1.53]	[0.58,1.10]
Chg. applied research work activities							0.80	1.21	0.78
							[0.62,1.03]	[0.58,2.53]	[0.55,1.11]
Chg. commercialization work activities							1.19	0.71*	0.91
							[0.98,1.43]	[0.52,0.98]	[0.74,1.13]
Chg. financial income							1.03	0.79	1.02
							[0.75,1.40]	[0.47,1.32]	[0.74,1.41]
Chg. freedom to choose projects							0.67***	1.68**	0.68*
							[0.53,0.85]	[1.16,2.44]	[0.50,0.93]
Ability									
Chg. self-perceived ability							0.83**	1.40**	1.10
							[0.72,0.94]	[1.10,1.77]	[0.94,1.28]
Chg. number of publications							0.95	0.98	0.80*
							[0.86,1.06]	[0.82,1.18]	[0.66,0.98]
Control variables									
Department NRC ranking (2010)	0.99	0.98	1.00	0.99	0.98	1.00	0.99	0.98	1.00
	[0.97,1.01]	[0.94,1.02]	[0.98,1.02]	[0.97,1.01]	[0.94,1.03]	[0.98,1.02]	[0.97,1.02]	[0.94,1.03]	[0.98,1.03]
Chg. thought about career	1.17	0.87	0.96	1.18	0.89	0.97	1.26*	0.84	1.01
	[0.98,1.40]	[0.64,1.18]	[0.76,1.21]	[0.99,1.40]	[0.65,1.21]	[0.76,1.24]	[1.05,1.52]	[0.54,1.31]	[0.78,1.30]
Male	0.91	0.53*	0.60*	0.89	0.50**	0.58*	0.74	0.44**	0.53**
	[0.54,1.51]	[0.32,0.86]	[0.39,0.91]	[0.54,1.47]	[0.31,0.81]	[0.37,0.88]	[0.41,1.34]	[0.26,0.77]	[0.33,0.85]
Chg. married	0.93	0.95	1.50	0.96	1.00	1.54*	0.99	0.92	1.51
	[0.66,1.30]	[0.54,1.67]	[1.00,2.26]	[0.69,1.35]	[0.55,1.85]	[1.02,2.32]	[0.66,1.48]	[0.48,1.74]	[0.99,2.31]
Chg. number of children	1.84	0.91	0.36	1.86	0.92	0.34	1.47	0.85	0.27
	[0.96,3.51]	[0.26,3.25]	[0.02,6.17]	[0.94,3.66]	[0.26,3.28]	[0.02,5.01]	[0.75,2.90]	[0.22,3.30]	[0.03,2.80]
Male X Chg. married	0.95	0.94	0.59*	0.91	0.85	0.58*	0.87	0.95	0.56
	[0.65,1.39]	[0.48,1.83]	[0.35,0.99]	[0.61,1.34]	[0.41,1.76]	[0.34,0.98]	[0.54,1.40]	[0.45,2.02]	[0.32,1.00]
Male X Chg. num. children	0.56	1.95	3.36	0.54	1.84	3.47	0.92	1.79	5.24
	[0.19,1.70]	[0.31,12.39]	[0.21,54.00]	[0.18,1.60]	[0.30,11.33]	[0.26,46.80]	[0.29,2.90]	[0.24,13.22]	[0.51,53.59]
US citizen	2.21**	2.14	1.65	2.26**	2.11	1.66	2.49**	2.08	1.73
	[1.25,3.90]	[0.75,6.10]	[0.83,3.28]	[1.29,3.97]	[0.71,6.25]	[0.82,3.36]	[1.41,4.39]	[0.52,8.40]	[0.78,3.81]
Parent is academic	0.94	0.81	1.14	0.93	0.81	1.13	1.01	0.93	1.17
	[0.62,1.44]	[0.33,2.00]	[0.62,2.10]	[0.60,1.43]	[0.33,1.97]	[0.61,2.08]	[0.63,1.62]	[0.32,2.66]	[0.63,2.17]
Started PhD in 2009	1.15	0.74	0.60	1.11	0.75	0.60	0.97	0.68	0.48*
	[0.77,1.72]	[0.41,1.36]	[0.34,1.06]	[0.72,1.71]	[0.40,1.38]	[0.34,1.04]	[0.55,1.71]	[0.35,1.33]	[0.26,0.88]
Race fixed effects	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Field fixed effects	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.

(*Continued*)

Table 5. (*Continued*)

Method	Multinomial logit								
Description	*Baseline*			*Labor market factors*			*Market & non-market factors*		
Dependent variable (relative to remain interested in an academic career)	Lose interest	Gain interest	Never interested	Lose interest	Gain interest	Never interested	Lose interest	Gain interest	Never interested
Model	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
University fixed effects	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Constant	0.21***	0.00***	0.13**	0.17***	0.00***	0.15**	0.11***	0.00***	0.14*
	[0.09,0.49]	[0.00,0.00]	[0.04,0.47]	[0.07,0.42]	[0.00,0.00]	[0.04,0.59]	[0.03,0.36]	[0.00,0.00]	[0.03,0.63]
Log pseudolikelihood	-778.17			-773.63			-692.11		
Obs.	825			825			825		

Relative risk ratios reported. Standard errors clustered by university; 95% confidence intervals of relative risk ratios in brackets;

*** $p < 0.001$,

** $p<0.01$,

* $p < 0.05$.

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may gain greater relevance later in the PhD program, perhaps because they are a more reliable proxy for ability than earlier in the PhD program.

Taken together, these results suggest that the predictors of career preferences are similar in both time periods, but that ability is more important closer to graduation. The latter observation may reflect that students gain a clearer understanding of the role of ability in academic success and re-evaluate the attractiveness of the faculty career in light of their own chances of performing well.

Some of the control variables also show interesting results. First, we asked students at both periods of time to what extent they had thought about their future careers. Model 3 in Table 5 shows that students who increased how much they thought about their careers were more likely to lose interest in academia. Second, the gender dummy and its interactions show that unmarried men find academia significantly more attractive than do unmarried women early in the PhD program (no significant difference between married men and women). Three years later, we find no gender difference in the attractiveness of academia among unmarried individuals but married women find academia significantly less attractive than do married men (Table 6). Finally, U.S. citizen PhD students rate academic careers significantly less attractive than foreign PhD students in both waves of the survey and they are significantly more likely to lose interest over the course of the program. These results for gender and citizenship are largely consistent with the descriptive statistics shown in Table 2, but further research is needed to examine the underlying reasons for the observed differences.

Auxiliary analyses. We perform three auxiliary analyses. First, recall that we found no significant association between changes in academic career interest and changes in labor market expectations, suggesting that students who lose interest in academia do not do so because their labor market expectations changed more than those of students who remain interested in academia. However, it could be that the same change in labor market expectations triggered a change in career preferences for some students but not others. In particular, students "at the margin" may respond to changed market expectations while those strongly committed to academia may not. To examine this possibility, we focus on students who had an interest in academia early in their PhD in 2010 and distinguish between those who were interested ("extremely attractive") and those who were marginally interested ("attractive"). As expected, nearly 40% of PhD students who are at the margin lose interest between 2010 and 2013 compared to 22% of PhD students who were highly interested. We then estimate for each subsample a logit

Table 6. Ordered logit regressions predicting levels of academic interest early and later in the PhD program.

Method	Ordered Logit			
Description	Early in PhD (2010)		Later in PhD (2013)	
Dependent variable	Attractiveness of academic research career			
	(5-point Likert scale)			
Model	(1)	(2)	(3)	(4)
Labor market expectations				
Availability of faculty positions	1.40	0.85	1.02	0.80
	[0.73,2.67]	[0.44,1.65]	[0.52,2.00]	[0.36,1.75]
Availability of industry positions	0.84	1.00	0.65	0.64
	[0.38,1.86]	[0.38,2.69]	[0.36,1.19]	[0.31,1.34]
Number of years of postdoc	1.08	1.07	0.90	0.93
	[0.95,1.22]	[0.92,1.24]	[0.79,1.03]	[0.80,1.07]
Availability of research funding	1.03	1.10	1.32**	1.12
	[0.89,1.19]	[0.94,1.28]	[1.08,1.61]	[0.96,1.32]
Work preferences				
Basic research work activities		2.68***		2.46***
		[2.15,3.35]		[2.04,2.96]
Applied research work activities		1.02		1.20
		[0.69,1.51]		[0.95,1.51]
Commercialization work activities		0.88		0.81**
		[0.76,1.02]		[0.70,0.94]
Financial income		0.89		0.67**
		[0.71,1.12]		[0.51,0.88]
Freedom to choose projects		2.12***		2.24***
		[1.62,2.79]		[1.83,2.74]
Ability				
Self-perceived ability		1.24***		1.48***
		[1.13,1.37]		[1.31,1.66]
Number of publications		1.04		1.03
		[0.94,1.15]		[0.98,1.09]
Control variables				
Department NRC ranking (2010)	1.00	1.00	1.01	1.01
	[0.99,1.01]	[0.98,1.01]	[0.99,1.02]	[0.99,1.02]
Thought about career	1.09	0.94	1.14	0.87
	[0.92,1.28]	[0.81,1.10]	[0.92,1.40]	[0.68,1.12]
Male	1.93***	1.66**	1.13	1.22
	[1.45,2.58]	[1.19,2.31]	[0.71,1.79]	[0.71,2.10]
Married	2.04**	1.73*	0.76	0.62*
	[1.31,3.17]	[1.03,2.92]	[0.52,1.11]	[0.41,0.95]
Number of children	0.62	0.62	0.86	1.02
	[0.37,1.04]	[0.34,1.10]	[0.44,1.70]	[0.57,1.84]
Male X Married	0.48*	0.70	1.60*	1.74
	[0.25,0.94]	[0.34,1.43]	[1.00,2.56]	[0.94,3.21]
Male X Num. children	1.59	1.30	1.50	1.16
	[0.74,3.42]	[0.67,2.49]	[0.73,3.09]	[0.61,2.22]
US citizen	0.66*	0.47***	0.71	0.44***
	[0.46,0.94]	[0.30,0.73]	[0.48,1.04]	[0.29,0.67]

(*Continued*)

Table 6. (*Continued*)

Method	**Ordered Logit**			
Description	**Early in PhD (2010)**		**Later in PhD (2013)**	
Dependent variable	**Attractiveness of academic research career**			
	(5-point Likert scale)			
Model	**(1)**	**(2)**	**(3)**	**(4)**
Parent is academic	0.93	0.85	1.09	1.06
	[0.63,1.36]	[0.57,1.27]	[0.86,1.37]	[0.81,1.41]
Started PhD in 2009	1.42*	1.32	0.95	0.94
	[1.06,1.89]	[0.95,1.82]	[0.68,1.33]	[0.65,1.36]
Race fixed effects	Incl.	Incl.	Incl.	Incl.
Field fixed effects	Incl.	Incl.	Incl.	Incl.
University fixed effects	Incl.	Incl.	Incl.	Incl.
Log pseudolikelihood	-948.94	-823.63	-1170.2	-945.81
Obs.	825	825	825	825

Odds ratios reported. Standard errors clustered by university; 95% confidence intervals of odds ratios in brackets;
*** p < 0.001,
** p<0.01,
* p < 0.05.

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regression predicting whether a respondent loses interest in the academic career. Results in Models 1 and 2 of Table 7 show that labor market expectations have no relationship with changes in career preferences in either sample.

Second, we simplify the analysis by using a change score as the dependent variable, computed as the difference between respondents' interest in a faculty career early (2010) and later (2013) in the PhD program. This variable ranges from -4 to 3, with a mean of -0.55 and 43% of respondents reporting no change (i.e., zero). Compared to our dichotomized primary measure, this variable reflects the extent to which career preferences change over the whole range, without relying on a qualitative threshold. At the same time, this measure does not distinguish between individuals who lose interest from a high starting level (e.g., from 5 to 4, for a change of -1) and those who lose interest from a low starting level (e.g., from 2 to 1, also for a change of -1). We regress this change score using an ordered logit regression. Model 3 in Table 7 uses the full sample and shows that the results are largely consistent with our main analysis: We find no significant coefficients of labor market expectations, but significant positive coefficients of changes in respondents' preferences for basic research and freedom, as well as changes in subjective ability. Moreover, we find that changes in the preference for commercialization activities are negatively related with changes in academic interest.

Finally, given that our sample size is too small to estimate multinomial regressions separately by field, we instead estimate models using the change score for our three largest fields: life sciences, physics, and engineering. The results (Table 7, Models 4–6) show no significant coefficients of labor market expectations. Changes in the interest in basic research are positively related to changes in academic career interest in all three fields, although the coefficients are larger in the sciences than in engineering. Among engineering PhD students, changes in the interest in commercial activities have a strong and significant negative relationship with changes in academic career interests. Thus, changes in preferences for different work activities appear to play a role in all three fields, although the particular activities that matter may differ depending on the dominant kind of work done in these fields [31]. We also find that changes

Table 7. Auxiliary analyses.

Method	Logit		Ordered Logit			
Dependent variable	Lose interest in academic research career			Change in attractiveness of academic research career		
	(relative to remain interested)					
Sample	Highly interested (acad. = 5)	Marginally interested (acad. = 4)	All fields	Life sciences	Physics	Engineering
Model	(1)	(2)	(3)	(4)	(5)	(6)
Labor market expectations						
Chg. availability of faculty positions	0.53	0.46	1.01	1.20	0.71	1.63
	[0.11,2.60]	[0.11,1.97]	[0.58,1.77]	[0.37,3.83]	[0.15,3.28]	[0.32,8.29]
Chg. availability of industry positions	2.71	1.72	0.80	1.90	0.61	0.25
	[0.39,18.90]	[0.43,6.91]	[0.53,1.18]	[0.70,5.10]	[0.18,2.07]	[0.05,1.17]
Chg. number of years of postdoc	1.25	0.88	0.98	1.14	0.91	1.10
	[0.72,2.17]	[0.69,1.12]	[0.87,1.10]	[0.93,1.40]	[0.68,1.20]	[0.91,1.33]
Chg. availability of research funding	1.08	1.05	1.11	1.04	1.03	1.18
	[0.66,1.77]	[0.80,1.39]	[0.96,1.29]	[0.75,1.43]	[0.61,1.75]	[0.75,1.85]
Work preferences						
Chg. basic research work activities	0.28***	0.40***	1.89***	2.28***	3.19**	1.75*
	[0.14,0.58]	[0.24,0.67]	[1.61,2.22]	[1.62,3.20]	[1.38,7.41]	[1.09,2.82]
Chg. applied research work activities	0.74	0.71	1.07	0.90	0.83	1.20
	[0.36,1.50]	[0.46,1.11]	[0.91,1.27]	[0.69,1.17]	[0.31,2.20]	[0.72,1.98]
Chg. commercialization work activities	1.12	1.28	0.84**	1.02	0.80	0.60***
	[0.72,1.73]	[0.92,1.78]	[0.74,0.95]	[0.75,1.39]	[0.57,1.13]	[0.45,0.80]
Chg. financial income	1.33	0.90	1.01	1.06	1.25	0.75
	[0.71,2.48]	[0.61,1.34]	[0.84,1.23]	[0.76,1.47]	[0.55,2.84]	[0.50,1.13]
Chg. freedom to choose projects	0.58	0.65*	1.67***	1.75***	1.02	2.02***
	[0.27,1.25]	[0.46,0.91]	[1.41,1.97]	[1.36,2.25]	[0.65,1.59]	[1.34,3.04]
Ability						
Chg. self-perceived ability	0.79	0.75**	1.28***	1.51***	1.31**	1.35*
	[0.62,1.02]	[0.60,0.93]	[1.19,1.39]	[1.23,1.84]	[1.08,1.59]	[1.06,1.72]
Chg. number of publications	1.15	0.90	1.05	1.06	1.02	1.09
	[0.80,1.64]	[0.76,1.06]	[0.98,1.13]	[0.92,1.22]	[0.74,1.40]	[0.90,1.31]
Control variables						
Department NRC ranking (2010)	1.00	0.99	1.01	1.02	0.99	1.02
	[0.94,1.07]	[0.95,1.02]	[0.99,1.02]	[0.99,1.04]	[0.89,1.10]	[0.98,1.06]
Chg. thought about career	1.04	1.42*	0.86*	0.84	0.68	0.80
	[0.61,1.77]	[1.04,1.93]	[0.76,0.97]	[0.64,1.11]	[0.35,1.31]	[0.59,1.07]
Other individual control variables	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Race fixed effects	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Field fixed effects	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
University fixed effects	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Constant	0.02*	0.22				
	[0.00,0.68]	[0.03,1.34]				
Log pseudolikelihood	-85.27	-160.7	-1132.58	-369.24	-172.67	-234.31
Obs.	240	335	825	302	145	192

Odds ratios reported. Standard errors clustered by university; 95% confidence intervals of odds ratios in brackets;

*** $p < 0.001$,

** $p<0.01$,

* $p < 0.05$.

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in the importance of research freedom are positively related to changes in academic career interests in the life sciences and in engineering, but not in physics, while changes in subjective ability are positively related to changes in academic career interests in all fields. Given the small sample size, these analyses should be interpreted with caution. However, they point toward the value of future work that more explicitly considers field differences in the dynamics of students' career interests.

Limitations

Before we turn to implications, it is important to highlight a number of limitations and opportunities for future research. First, although we explored a number of market and non-market reasons that may underlie changes in students' interests in the faculty career, there may be other reasons that we were not able to examine. Relatedly, our focus was on changes in students' academic career interests and future research is needed to study whether and why students also experience changes in their interests in non-academic careers. Second, we described some differences in the dynamics of career preferences by field and demographic characteristics. Unfortunately, the sample is not large enough to perform a more systematic analysis of potential drivers of changes in career preferences for different sub-populations. Third, the use of multiple survey questions for a given construct can increase reliability and researchers' ability to detect relationships among variables. Although the use of single item measures allowed us to reduce respondent burden and to explore a broad range of factors, future work should examine key relationships using multi-item measures. Finally, our data do not speak to the dynamics of career preferences outside of science and engineering fields.

Although we are not aware of other longitudinal data on PhD students' career preferences, a survey sponsored by the Pew Charitable Trust in 1999 covered a broader range of fields and included a question asking PhD students retrospectively whether their interest in becoming a professor in a college or university had changed since the start of the program [16]. The Pew survey showed that the shares of students who reported a decreased interest in this career was considerably larger in the biological sciences and the physical sciences (43% and 40%, respectively) than in the humanities and the social sciences (29% and 32%). Although major differences in question formats and samples do not allow a quantitative comparison with our data, the Pew study reinforces some important points: First, changes in career preferences over the course of the PhD training are considerable, and there is strong evidence in particular for a decline in students' interest in the academic career path. Second, while such changes likely occur in all fields, they appear most pronounced in the physical and biological sciences.

Discussion

We reported a range of complementary analyses that yield a number of key insights. We now summarize these insights and discuss important implications. First, although labor market conditions almost certainly prevent some graduates who are interested in an academic career from obtaining a faculty position, we find that a substantial share of PhD students lose interest in an academic research career for reasons other than labor market conditions. As such, efforts to understand students' career paths should consider the diversity in career goals and a broad range of factors that shape these goals. In particular, comparisons of the number of graduates with the number of available faculty positions [2, 7, 8] likely overstate the number of PhDs who aspire to a faculty career, thereby exaggerating imbalances in academic labor markets (see also [4]). This insight provides urgency to the National Academies' recent call for better data on students' career preferences [6] and we present a measure that may be useful in such data collection efforts.

Second, there is considerable heterogeneity in the degree to which career preferences change. While many students remain highly interested in an academic research career, others report a significant decrease in their interest in academia. The large share of students who remain interested alleviates concerns about a potential "drying up" of the pipeline of highly trained scientists pursuing academic careers. While the declining interest in academia among other students may concern observers who believe that all PhDs should aspire to a faculty career, these changes may also be seen as positive to the extent that they result in a better alignment between students' career preferences and the careers they ultimately enter.

Third, a significant share of advanced students– 40% in our study—are not interested in pursuing an academic career. Given that many students report a lack of information about non-academic career options [15] this finding suggest that better information about a variety of career pathways earlier in the PhD may be beneficial [6, 32]. Workshops and information sessions are offered by many institutions [33] but may have a limited ability to truly convey what it means to work in other sectors. Experiential approaches such as internships may be more effective by allowing students to experience non-academic careers first-hand. Moreover, there is the concern that career exploration may be hindered by a lack of support from advisors, who tend to strongly encourage the traditional academic career path [4, 34]. As such, allowing students the time to explore different career options and creating an open culture that acknowledges changing preferences and that values non-academic career paths may be important complements to offering richer information [7, 35]. Students, in turn, should begin to consider their careers early on and take advantage of the career exploration opportunities provided by their advisors and programs.

It is well recognized that graduate schools need to prepare PhD students for a variety of academic and non-academic careers [6]. Several innovative initiatives—such as NIH's BEST program—are important steps towards this goal. Our results suggest that such initiatives need to take a dynamic perspective to accommodate changing career preferences over the course of graduate training. In particular, if students enter PhD programs aspiring to faculty careers, they are unlikely to take advantage of opportunities to explore non-academic options right away. In addition to encouraging students to explore different career options and interests, programs should thus provide students with the flexibility to adjust and modify program components as their career goals change.

Finally, future research is needed on whether and how some of the learning that appears to underlie the observed changes in career preferences can be accelerated or even moved *prior to* students' enrolling in a PhD program. More explicit assessments of their own interests and abilities, as well as more realistic evaluations of career options may lead some individuals to realize that pursuing a faculty career, and a PhD, is not the best way forward for them. This may allow individuals to take advantage of a growing range of alternative educational options, such as professional science master's programs, and ultimately result in faster career progress and more satisfying long-term career outcomes.

Supporting information

S1 Table. Variables and measures.
(DOCX)

S1 Text. Survey questionnaire.
(DOCX)

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Writing – review & editing: Michael Roach, Henry Sauermann.

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Thank you for submitting your manuscript to PLOS ONE. After careful consideration, we feel that it has merit, but is not suitable for publication as it currently stands. Therefore, my decision is "Major Revision."

Thank you very much for giving us the opportunity to revise this manuscript. We appreciate the reviewers' feedback and we made several significant changes to address their comments and concerns. We believe the manuscript is much better as a result.

We invite you to submit a revised version of the manuscript that addresses the points below:

Both reviewers have offered thoughtful comments. I would especially encourage you to think about the issues that are raised by Reviewer #2. This reviewer is essentially pushing you to think more formally about how to convince readers that the change in career goals reflects changes in opinions or attitudes vs. changes in knowledge over the course of students' graduate careers. As the reviewer points out, doing so requires formalizing this conjecture and articulating a (multivariate) statistical framework in which these alternative hypotheses can be tested. Reviewer #1 makes a number of valuable points as well that you should consider should you choose to revise your submission.

We believe that we were able to address most of the points made by Reviewers 1 and 2 and provide a detailed response below. Reviewer 2's comment you highlight led us to completely rethink our regression analyses, which now complement the nonparametric analyses in a more systematic way. More importantly, we follow Reviewer 2's conceptual model by examining three primary reasons for changes in career preferences: Changes in the X variables (tested using multinomial regressions), changes in the coefficients of the X variables between the two time periods (tested in a set of ordered logit regressions), and starting levels of key X variables. We add a number of robustness checks that provide complementary insights.

I would also ask that you provide some elaboration regarding the availability of the data and share more information about the survey instrument, etc.

Please see #6 below.

3. Please state whether you validated the questionnaire prior to testing on study participants. Please provide details regarding the validation group within the methods section.

To provide details on the validation of the survey instrument, we added the following to the Materials & Methods section: "The questionnaire was validated by inviting a select sample of PhD students at the investigators' universities to complete the survey followed by an exit interview to probe students' understanding of key questions and to solicit feedback on the instrument."

4. Please include a copy of the survey questions or questionnaire used in the study, as Supporting Information, or include a citation if it has been published previously.

We have included the survey questions used in this study in S1 Text.

5. Please provide in your methods section a separate section with the statistical analysis used in this study.

Since the precise statistical methods used in this study vary for the different analyses, we provide details of each method with the corresponding findings in the Results section.

6. We note that you stated "data are available upon request" at submission. Could you please upload the minimal data set underlying the findings in your study in the manuscript, supplemental files, or in a stable public repository? If this is not the case, and your data are available upon request because of an ethical or legal restriction, or because you obtained data from a third party, please include the following in your revised cover letter:

A public-use data set with selected variables will be made available at Harvard Dataverse upon publication of the article. This data set allows the replication of key descriptive results. Unfortunately, the full micro-data cannot be released due to IRB disclosure restrictions and a confidentiality agreement with the respondents.

Reviewer #1

"Labor market expectations and the declining interest in an academic career," examines longitudinal trends in STEM PhD students' interest in an academic career as well as associations between labor market expectations, job attribute preferences, individual characteristics and academic career interests. The authors are to be commended for examining an important issue in STEM education and workforce development. The large sample size and longitudinal design are also clear strengths of this study. However, there are several issues that need to be addressed to improve the quality of the manuscript. I hope the following feedback is helpful to the authors in improving the manuscript.

Thank you very much for reviewing our manuscript and for your many helpful comments and suggestions. We made significant revisions to address your feedback.

1. At present, it does not appear that the statistical analyses performed in the study necessarily substantiate some of the claims made by the authors. For example, the authors suggest that it is primarily job attribute preferences that appear to be driving the decline in interest for an academic career observed among their participants. It would seem that a significant increase in variance above and beyond that observed for labor market expectations or a mediation analysis would need to be performed to substantiate this claim.

We hope that the revised manuscript explains more clearly the logic of our argument. Allow us to summarize a few key aspects:

Our key premise is that factors that explain changes in career preferences should differ systematic between students whose career preferences change and those whose preferences remain unchanged. As such, our nonparametric analyses (visualized in Figures 3 to 5) compare levels and changes of variables such as labor market expectations and job attribute preferences between these two groups. We find that both groups of students experience very similar changes in career expectations, which suggests that these variables do not explain why some students change career preferences while others do not. The regression models reported in Tables 5 and 7 address this issue even more directly by showing which independent variables are correlated with changes in academic research career preferences. Changes in labor market expectations have no correlation with the dependent variable, again suggesting that they have no significant power in explaining changes in career preferences (while some of the other variables do).

Finally, although we cannot perform a standard analysis of variance explained due to the nature of our measures, the regressions shown in Table 5 now introduce labor market expectations and other variables as separate blocks, allowing us to compare the change in the log likelihood (LL). Model 1 includes just the control variables and has a LL of -778. Introducing the labor market expectations changes the LL very little, to -773. However, adding measures of interests in work activities, job attributes, and of ability changes the log likelihood substantially to -692. In conjunction with several highly significant coefficients among the latter set of variables, this is evidence that these variables have considerable explanatory power, while job market expectations do not.

2. The measures used in the study have significant limitations. In all cases, a single item is used to measure each construct. This reduces the degree to which each construct is sufficiently captured (i.e., limited content validity) and calls into question the validity of the findings. The dichotomized scoring method used for

some of the measures, including interests, is also questionable. For example, participants who indicated they found academic research careers "neither attractive nor unattractive" were categorized as "not interested" in an academic career. How do we know that given the choice (e.g., interested or not interested), these participants would have answered in the affirmative or negative?

We agree that multi-item measures would be preferable. We now discuss this limitation in a separate section of the paper ("Limitations") and also explain the rationale for using single-item measures in the current study.

Dichotomizing the career interest measure allows us to distinguish different groups of respondents by the presence and direction of change (e.g., remain interested, lose interest, gain interest, never interested), which is conceptually important and also makes the nonparametric analyses much more intuitive. However, we appreciate your concern that dichotomization may be problematic. As such, we included a series of additional analyses that do not rely on the dichotomized measure. In particular, models reported in Table 6 use the original measures of academic research career interest and are estimated using ordered logit regressions. We also estimate models using simple change scores that do not involve any dichotomization (Table 7). These analyses provide additional evidence that corroborate our main findings, and we thank you for pointing us in this direction.

3. The Introduction is not sufficiently developed to ground the problem under investigation. Portions of the Introduction on pages 2-3, which discuss results and implications of the research, seem more appropriate for the Results or Discussion sections. Instead, more background could be provided on the growth of STEM careers generally along with comparable rates of growth (or lack thereof) of academic positions. More context could also be provided for the typical tasks and demands of STEM academic careers, given a central thesis of the manuscript appears to be that these work activities become less desirable to students over the course of their training. For example, I wondered if extant data on STEM faculty reports of their work experiences might be helpful to readers.

Thank you for highlighting these opportunities for improvement. We now reduced our discussion of results in the introduction to a minimum. In response to your suggestion, we also added a discussion (and Figure 1) on general STEM labor market trends with respect to PhD graduates and faculty positions. We agree that this discussion provides an important context and motivation for our study. Moreover, we added a section on "Background" that discusses typical tasks and challenges of the faculty career and also draws on recent work showing what faculty spend their time on. This discussion provides additional useful context and pre-figures some of the factors we examine in the empirical part of the analysis. Thank you again for this suggestion.

4. I also had questions about the sampling methodology. What does recently matriculate mean on pp. 3? Does this mean all students were in their first year or does "recent" imply they could have also been in their second year of study?

We apologize for the lack of clarity in our description of the sample. By "recently matriculated" we refer to PhD students who were in the first or second year of their PhD studies at the time of the survey. We clarify this in the text by including the following: "PhD students who were in the early stages of their graduate studies in 2010 (i.e., first or second year students) and in advanced stages of their studies and nearing graduation in 2013. In our study 62% of respondents were in the second year of their PhD in 2010."

Perhaps I missed this as well, but was the survey administered in the Fall or Spring semester? In my experience, students seem to be more energized and optimistic in the Fall, which could have implications for their initial survey responses.

We first administered the survey in February 2010 and gathered responses through April 2010. The second wave of the survey (2013) was also administered in the spring semester. We revised the text to include the month of initial contact.

The authors could provide context for the response rate of 30% and how this might have affected the validity of the results. Is a 30% response rate typical of online survey research? A citation would help here.

A recent paper on web survey response rates specifically in the Science and Innovation context suggests that response rates tend to be relatively low, often in the 10-20% range (*1*). As such, our response rate of 30% is on the higher end of what appears to be typical. We also confirmed that our baseline survey is not subject to nonresponse biased based on observable characteristics of our population such as field, university, and year of matriculation. For the current study, we also performed an analysis to examine response rates for the second wave of the survey and find that respondents' attractiveness of a research faculty career in the first wave does not predict nonresponse to the second survey, nor does their expectation of the likelihood of PhDs obtaining a faculty career. We do find, however, that males are less likely to respond to the second survey and U.S. citizens are more likely to respond. We now discuss nonresponse tests in more detail in the paper.

I wondered if a substantial amount of drop-off in the response rate between times 1 and 2 of the survey might be attributable to non-persistence decisions, which in some STEM areas tend to occur after the first year of study. Do the authors have information on this?

We note that the response rate for the second wave (44% conditional on response to the first wave) was substantially higher than that for the first wave (30%), which presumably reflects that certain individuals are intrinsically more likely to respond or to be interested in this particular survey. The second wave of the survey asked addressees to respond regardless of their current labor market status and while many were still students (used in this paper), others had graduated, and some had left the program without graduating. It is possible that some survey invitations did not reach their recipients if students dropped out of the program, university email addresses were de-activated, and respondents had not provided us with a private follow-up email address in 2010. Unfortunately, we cannot examine this possibility since the survey software Qualtrics did not at that point provide individual level information on emails that bounced back.

Although we do not believe that dropouts pose a major problem for our study, any existing bias would presumably make our results conservative. In particular, one would expect dropouts to be more likely among students who lost interest in the academia career (and thus did not find pursuing a PhD worthwhile) such that the observed changes in our data may be a lower bound.

5. While several of the analyses are statistically significant, the practical significance of the findings is questionable. The authors need to report a measure of effect size to present the practical significance of findings related to their t-statistics, which are likely affected by sample size. It is also unclear what statistical analysis the authors used to substantiate the finding that a greater

percentage of men start the PhD with an interest in an academic career relative to women (chi-square test, t-test?). Without this information, the validity of the findings cannot be determined.

We now report greater detail on the tests performed, including test statistics and significance levels.

We also agree that the economic significance is important. For the results reported in Tables 3 and 4, as well as Figures 3-5 the economic significance should be apparent directly. For example, the observation that the share of students interested in an academic career drops from 80% to 55% (Figure 2) can be interpreted directly, and the economic significance of this change is large. Similarly, the observation that the share of students who believe funding in academia is readily available declines from 39% to 16% should also be intuitive and economically significant.

Results are typically more difficult to interpret in the context of regression analyses. To address this challenge, we re-estimated all models and report results in terms of odds ratios. We hope that readers will find odds ratios easier to interpret than raw regression coefficients.

Taken together, we suggest that the practical significance of observed changes in career preferences, as well as of changes in some of the right-hand side variables is considerable.

6. The use of a single quote on pp. 17 to substantiate speculation about the quantitative findings is questionable. I would recommend this qualitative data be excluded from the study since it appears to be purely anecdotal rather than based on any systemic analysis of responses.

We agree. We have removed the qualitative data from the discussion of alternative reasons.

7. The Discussion would benefit from more thoughtful interpretation and insights into practical implications. As the authors note on pp. 18, some might interpret these findings as an indication that students are choosing careers that are more in line with their skills and interests. Do we know how these rates of losing interest compare to those of other fields (i.e., are they atypical)? In terms of drawing out the implications a bit more, the authors could provide additional information on how faculty advisors and university administrators should support students in their career exploration. Most universities already offer personal and career counseling services. What additional supports could be offered?

We agree that comparative insights from non-STEM fields would be very valuable. Given that our survey did not include such fields, we searched for evidence in other research. While we could not locate evidence based on longitudinal data such as ours, a study sponsored by the Pew charitable trust provides some useful data based on a retrospective survey (*2*). These data suggest that decreases in students' interests in becoming faculty are common in all fields but may be most pronounced in STEM. We discuss this prior work in the new section "Limitations".

Other Minor Issues

1. "R & D" needs to be spelled out initially for the reader who might be unfamiliar with the term.

Thank you for pointing this out. We have spelled it out in the first sentence of the manuscript.

2. Given the vast underrepresentation and exclusion of people of color in STEM fields, I found it striking that the authors limited their comparisons of subgroups by demographic factors to gender and nationality. If the author has access to this information, I believe it would be helpful to report.

Unfortunately, we do not have a sufficient number of observations to explore underrepresented minorities in greater detail. However, we now include race categorical variables as controls in our new analyses.

3. The authors should avoid providing interpretations of the findings in the Results section and instead save these for the Discussion.

We have moved the more general interpretation of the results and the implications to the discussion section. However, given the number of analyses in this study we still discuss the interpretation of our findings with each set of analyses.

4. On pp. 11, the author describes ratings of availability of funding to faculty members being rated on a "3-point scale ranging from 1 ("extremely low") to 5 ("extremely high")." Some additional explanation is warranted here to describe how three reference points were used to establish a 1-5 rating.

We apologize for the typographical error. It should have read "5-point" scale. We have corrected the text to reflect this.

5. Table 4 could be improved for clarity. Are the authors reporting odds ratios or beta weights in this table?

We apologize for the lack of clarity. We re-estimated all tables, report odds ratios, and provide explanation in the table headings/footnotes.

Thank you again for your many helpful comments and suggestions. We made significant revisions to incorporate your feedback and look forward to any additional suggestions you may have.

Reviewer #2

This is a very interesting study on a topic not sufficiently studied: What are the career plans of those entering STEM PhD degree programs and how does the graduate school process affect these career plans? The paper is based on a very interesting survey and generally uses appropriate empirical approaches. I do see here clear evidence that changes in expectations of faculty positions or of industry positions seem to not be responsible for changing attitudes over time in academic career interests among STEM graduate students, as the authors argue.

Thank you for reviewing our manuscript and for your insightful and extremely valuable comments and suggestions. We have significantly revised to paper to address many of your concerns and now include new analyses and results as detailed below.

A. My first major critique and suggestions relate to readers' inability to fully parse out from the results how much of career choices (academic/not) can be attributed to (1) people's initial opinions/beliefs/characteristics going into graduate school; (2) changes in people's opinions/beliefs/characteristics while in graduate school; and (3) changing importance (coefficients) of opinions/beliefs/characteristics while in graduate school. Some of the graphs are suggestive about some aspects of this, but we must look to the multivariate regression analysis to isolate impacts of separate effects. However, the regression models presented simply do not allow us to know which is important – (1), (2), or (3) -- nor the magnitude of any of these effects […]

In sum, this critique suggests adding a table of original average X values and changes in the average X values, (probably) estimating only Models 1 and 3, and interpreting the results more carefully in terms of what we learn from each, and applying these models to the level and changes in X's to decompose what causes people to prefer different careers and what changes these preferences while in graduate school. (For instance, from model one column 1a we can conclude that those who lose interest are really different to begin with than those who remain interested – but only in terms of a couple of things.)

Thank you very much for highlighting this weakness of the prior version and for pushing us towards a more systematic way of thinking about these issues.

In response to your suggestion, we now provide extensive descriptives in both figures 3-5 and tables 3 and 4. The tables also provide statistical tests for the difference in means both within each group over time and between groups at each point in time.

More importantly, we completely revised our regression analyses based on your feedback and conceptual ideas. In particular, we now address more systematically three key possibilities:

(1) First, we start from the intuition that a change in Y may be driven by a change in X (your point 2 above). That intuition underlies our discussion of figures 3-5 (do the

changes over time differ for the two groups). In the regression analyses, this possibility is explored in the multinomial logit regressions reported in Table 5.

(2) As you point out, it may also be that changes in Y are driven by changes in the coefficients of X (your point 3). To explore changes in coefficients, we now use cross-sectional data from both survey waves (i.e., 2010 and 2013) in a series of ordered logit regressions in table 6. Find little evidence of changes in coefficients.

(3) Finally, it may be that starting levels of X also matter. To examine this possibility, we estimate a multinomial logit model with RHS variables as of 2010 (Table 6, model 5).

As you point out, labor economists have developed an integrated approach to examine the degree to which differences in outcomes between groups are explained by differences in levels of independent variables and by differences in the coefficients of independent variables (*3, 4*). Unfortunately, this approach is difficult to apply here since our goal is to explain differences over time (rather than between groups) and since our outcome variable is not continuous. However, the separate analyses we perform provide useful insights in a similar spirit. Taken together, the strongest evidence points towards the role of changes in X – in particular of preferences for work activities and job attributes. There is limited evidence of changes in coefficients or for the role of starting levels.

B. Controlling for "job attribute preferences" is quite problematic. Is there really a difference between "academic career differences [preferences]" and "job attribute preferences", especially those directly related to what one does for work such as the preferences for "basic research work activities" v. "commercialization work activities" and "applied research activities"? Aren't these just two ways to measure the same career interests? At the very least, the authors should re-estimate the regression model(s) dropping these job attribute preferences variables and see how and whether that affects all other coefficients, and what we can learn from it. This might possibly lead the authors to a radical change in the regression models, for instance modeling the changing job preferences as alternative Y variables. Or, if the other variables don't change much, it might just be a minor note and an additional table in the Supplement.

Thank you for raising this point. We see "macro" career preferences and "micro" job attributes preferences as quite distinct, both conceptually and empirically (see also *5, 6*). While some job attributes might be more readily available in specific careers, such as basic research in academia, other job attributes, such as applied research and, to some degree freedom and pay, may be offered across a variety of careers. At the same time, we agree that it would be good to assess whether including job attribute preferences impacts the coefficients on other variables. As such, we now include regressions that exclude preferences for job attributes in Table 5 with identical results for other key variables. Moreover, new results in Table 6 show the association between preferences for job attributes and the attractiveness of a research faculty more explicitly. While some of these relationships are quite strong, not all of them are, and the existing relationships are far from deterministic (while interest in basic research strongly predicts academic career preferences, even many of the students who lost interest in academia find basic research interesting, see also Fig. 4).

C. Here's an example that shows the importance of this last point: As I look at the regression results, I note that the authors did not mention the results about "self-perceived (research) ability." They really need to – it is a key and interesting variable. When people start graduate school (2010 Model 1), those who perceived their research ability to be low were more likely to be not interested in that career (column 1c). In Model 3, we learn that a positive change in this variable decreases the likelihood that a person loses interest in an academic career while it increases the likelihood that a person gains interest.(Model 3). How large was the change in self-perceived research ability during graduate school for each of the 4 outcome groups? (For this, we need the table of averages). Moreover, could this be a cause of the changing preferences for basic research work activities?

We agree that ability is important aspect of this study that was underexplored. We now promoted ability to a major section of potential reasons. As such, we now provide more detailed summary statistics, a new figure, and a discussion of ability in our regression analyses.

D. I have a fundamental problem with Figure 2. Isn't the main fact that we learn from this graph a tautology? After all, since your definition of interest an academic career is whether or not they answer 4 or 5, those who lose interest in an academic career by definition moved from a 4 or 5 to a 1,2,3. [Note that if you were to graph people who started interested in an industry career but lost interest, using the same 4/5 v. 1/2/3 measure, the graph would look about the same.] So this graph needs to be rethought. This is a similar problem in some of the text, e.g. in the final section (p18) "with most losing interest entirely"…. That is true by definition.

We agree that this discussion lacked clarity. We have dropped this figure and the associated discussion.

E. Based on Table 1, I am not convinced that the fields are not really different. To argue that they are similar, the authors compare the percentage of the whole population who lost interest. But the right measure to compare is "what percent of people who went into graduate school wanting an academic career later lost interest?" and here the numbers range from 50% in chemistry to 19% in computer science. (The other fields are very similar to each other, 28% to 31%). These two fields are definitely different. I would like the authors to do more analysis – at least of these 2 fields separately from the others. This analysis could be relegated to the supplement, but the results would be likely to change some of the discussion and conclusions of the paper.

While we have kept the table that reports the differences across fields, we no longer make the direct comparison that was of concern. However, we agree that field differences are of considerable importance and interest. As such, we now include regressions by main field in Table 7 as a robustness check. Although the results are largely similar across fields, there

are some subtle differences that we are unfortunately unable to explore in greater detail due to the relatively small sample sizes in each field. We note the need for future research on field differences in our discussion of limitations of the current study.

G. The authors don't talk a lot about what caused people to gain interest in an academic career -- admittedly a small group but worth a few sentences. Interesting to me is that this change was mostly due to increasing appreciation of freedom to choose projects and to increasing self-perceptions of research ability, rather than increasing interests in basic science.

While we agree that this an interesting group, as are PhD students who are never interested in an academic career, we decided to keep the focus of this study on students who start the PhD interested in an academic career but lose interest over time. One reason for this decision was that the number of cases in the other groups was quite small, making it difficult to draw strong and reliable conclusions from the data. Moreover, the mechanisms behind increasing interest in academia may be quite different from those behind a declining interest (as you point out), but seriously considering those different explanations would make the analyses overly complex and may detract from the focus of the paper. That being said, we agree that these cases are fascinating – especially given the general trend towards a decline in academic interests – and deserve closer study in future work.

H. How exactly is Model 3 estimated? It claims to use changes in academic career interests as the dependent variable and changes in the X variables as the explanatory ones, but how is there a change in the indicator variables of Male and "Started PhD in 2009", or in Dept NRC ranking (or field or university). The authors need to clarify this. I am guessing that some of these variable are not entered as changes. In light of this, the authors might rethink some of the things they say about this model.

You are correct, and we apologize for the lack of clarity. We now describe our regression equations in more detail, showing both time variant and in-variant controls. Variables that are time-variant are now clearly labeled using the prefix "chg" (for change).

I. The authors should include their survey instrument (questionnaire) in the supplementary material. While they do already give the survey questions about X variables (Table 3), I would like to know more about the questions related to the Y variable, to the questions about career interests and the alternative kinds of careers listed, whether they asked other kinds of questions on self-perceived ability, etc..

We now include the questions for all main dependent and independent variables.

J. The authors need to interact family variables with gender. It is well known that these factors affect men and women differently in all career-related outcomes.

We included interactions between gender and children as well as marital status. Cell sizes for some of them are quite small but we do indeed find some evidence of differences (especially in table 7). Thank you for pointing out this important issue.

K. Page 17: "Many students lost interest" should be more specific. About 1/3 of students lose interest.

This phrase is not in the revised manuscript.

Thank you again for your feedback. Your comments – especially regarding the structure of the empirical analysis – have led to very significant improvements in the paper. We look forward to any additional feedback you may have.

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The declining interest in an academic career

Response to reviewers

Editor

Thank you for submitting your manuscript to PLOS ONE. After careful consideration, we feel that it has merit but does not fully meet PLOS ONE's publication criteria as it currently stands. Therefore, we invite you to submit a revised version of the manuscript that addresses the points raised during the review process.

Thank you very much for giving us the opportunity to revise this manuscript. We appreciate the feedback from you and the reviewer and did our best to address the concerns and suggestions. We summarize key points in our response to your letter and provide a detailed reply to reviewer 2 below.

Reviewer 2 has read your revised manuscript closely and raises a number of important points. I will not reiterate them here, but the key issues revolve around the consistency of the different approaches you have adopted. Overall, I think it would help to articulate a more coherent analytical/theoretical framework about the likely relationships between career goals, information and other preferences, even if the point is that they are highly jointly determined. Such an approach might, as well, suggest whether the regressions in Table 6, relating changes in career goals to point in time measures can be sensibly interpreted. Of course, it may be easier per the reviewer's suggestion to simply drop this part of the analysis.

We now pursue a clearer empirical approach to studying change in career preferences. In particular, we dropped any analyses that do not follow the same underlying conceptual model, which included dropping Model 5 in Table 6 as well as the analysis of most preferred careers after the change. The current set of analyses is now even more closely aligned with R2's suggestions from the prior round.

Second, the reviewer raises some important questions about the interpretation of results reported from the different analyses and the extent to which they are in fact consistent with one another. You should address this directly.

We carefully went through the results again and expanded our discussion of the connection between the different models. Many of the key results are consistent throughout all models. We focus our summary of key insights in the discussion section on those results that emerge consistently throughout the set of complementary analyses.

One of the main concerns raised by R2 was about the significance of the relationship between the change in labor market expectations and change in career preferences. We had failed to clarify that the reported standard errors are for the odds ratios reported in the tables rather than the underlying raw coefficients (we had switched to odds ratios in response to R1 in the prior round). We now clarify this point in the paper and explain exactly how the standard errors are computed in the response to the reviewer below. There is no change to the size or significance of these coefficients compared to the prior versions of the manuscript. The lack of a significant relationship between market expectations and the change in career preferences as measured in our survey remains a key insight of the paper.

Third, I share the reviewer's concern about the "measure of change" score (Table 7). This dependent variable is not adequately explained, and is not obvious how it is calculated.

We apologize for the incomplete description of this variable. We now describe in detail that the variable was computed as the difference between attractiveness scores in 2010 and 2013. As such, it ranges from -4 to +3 (the theoretical maximum is +4 but this value is not observed in the data), consistent with what the reviewer states is appropriate for our purposes.

Finally, please consider the range of minor points raised by the reviewer.

We carefully went through R2's other points and provide a detailed response below.

Thank you again for inviting a revision. We hope the revised manuscript meets your expectations and look forward to any additional feedback you may have.

Reviewer 2

I thank the authors for doing such a major revision in light of my suggestions. The authors have addressed all of my main concerns in my previous report. With such a major re-write, I have done a major re-read. I do have some additional suggestions for needed changes of this new paper. My suggestions are not as major as previously, although they are not trivial.

Thank you very much for taking the time to read our paper carefully and for sharing your many helpful suggestions. We revised the paper in response to your comments and believe the paper has improved considerably as a result.

My major suggestions concern inconsistencies across the models. There are now 5 different ways they measure how important specific preferences and expectations are in explaining academic job favorability:
A. Nonparametric (no controls) Figures and Tables 3 and 4: comparing relationships between each preference/expectation variable and the change in academic job favorability measured by comparing those who remain interested and those who lose interest.
B. Multinomial logit with controls, Table 5: comparing relationships between the change in each preference/expectation variable and the change in academic job favorability measured by comparing those who remain interested and those who or lose interest (and those who gain interest and those never interested) controlling for all other factors.
C. Ordered logit of academic job interest with controls, Table 6 columns 1-4: comparing relationships between levels of each preference/expectation variable and academic job interest measured as a 5-value variable using ordered logit, controlling for all other factors, for 2010 and 2013 separately.
D. Multinomial logit with controls, Table 6 columns 5a-5c: comparing relationships between the 2010 (beginning) level of preference/expectation variable and the change 2010 to 2013 in academic job favorability measured by comparing those who remain interested and those who or lose interest (and those who gain interest and those never interested) controlling for all other factors.
E. Table 7: The authors are not clear in their description the dependent variable which they call "simple change score" which they analyze with an ordered logit. They may be comparing relationships between the change in each preference/expectation variable and how much academic job interest changed, i.e. – since the interest scale goes from 1 to 5 – this change goes from -4 to 4. What concerns me is that the "simple change score" might be the absolute value and thus goes from 0 to 4, since the authors say that this measure "does not allow us to distinguish individuals by the direction of change in interest." They also do this estimation for the 3 largest fields separately.

The authors present the results for all these models to suggest that all of these 5 kinds of analysis give the same results. I agree for some preference/expectation variables, but not for all. My suggestions and concerns are:
*1. As I thought through where inconsistencies were, I realized that several inconsistencies were between other models and Table 6 columns 5a-5c (what I called model D above), which uses 2010 preference/expectation levels to explain 2010-2013 changes in academic job favorability. (I note some of the inconsistencies below). This model doesn't make a lot of sense to me anyway, because to explain what happened in 2013, you need either to use 2013 preferences/*expectations (C above) , or the change in these preferences between 2010 and 2013 (B above*). Therefore, the authors should cut out the models in 5a-5c completely.*

We agree and deleted model 5 in Table 6.

2. My second suggestion is that the authors must explain the dependent variable in Table 7 (model E above) much more clearly. Further, (a) if this variable does NOT go from -4 to 4, then the current Table 7

needs to be thrown out and re-estimated based on a dependent variable that does go from -4 to 4. Alternatively, if the main reason for this model was to estimate something for the specific fields, they could just add on field-specific estimates of Table 6 Column 4. (b) If this variable DOES go from -4 to 4, then the authors need to make this much clearer in the text on page 24. Also, they need to throw out the sentence, "does not allow us to distinguish individuals by the direction of change in interest" since it is distinguished by being a negative change. I return to this in point 3b below.

We apologize for the lack of a clearer description of the construction of the dependent variable for Table 7. This measure is indeed the difference between the attractiveness as measured in 2010 and that measured in 2013 and ranges from -4 to +3 (the theoretical max is 4, but none of our respondents changed from 1 to 5). Our comment on the limitations of this measure was incorrect in that it can of course distinguish between people whose preferences increased and those whose preferences decreased. The point we were trying to make was that the ordered logit analysis using this score does not distinguish between these two cases, which is a limitation compared to the mlogit in our featured analysis (which estimates separate coefficients for those whose interest increases and those whose interest decreases). We now explain the variable in more detail and dropped the confusing statement about the direction of change.

3. For my next few suggestions, I point out inconsistencies among the analyses of major hypotheses (assuming they cut out Table 6 model 5). One of their major points is that people who want to enter academia prefer basic research, and decreases in these preferences for basic research coincide with losing interest in academia. We do see this consistently in all of the analyses (except Table 6 model 5 to be cut out). A second major point is that people who want to enter academia prefer freedom to choose projects, and losing these preferences coincides with losing interest in academia. We also see this consistently in all of the analyses (except Table 6 model 5). Interestingly it is not true for physics alone (Table 7), an exception which is mentioned. A third major point is that people who believe that they are very able are more likely to want academic careers. We also see consistent results for this (except Table 6 model 5).
However: a) A fourth major point is that those who lose interest in academia also start liking commercializing activities more. Here, the authors need to address inconsistencies. This IS indicated in some of the analyses. However, we do NOT see this as a significant effect in the important Table 5 column 3a which measures changes (model B), although the sign is as expected. The authors did not mention this inconsistency. Also, we do not see this in levels in 2010 (Table 6 Model 2). The authors only mentioned this in the context of the 2013 and 2010 coefficient not being significantly different, ignoring its insignificance in 2010. The authors need to address the fact that given inconsistent results, this is not a certain, major effect. If possible, the author can explain why it is true in 2013 levels ceteris paribus.

Thank you for pointing out this issue. As you note, the relationship between interest in commercialization and career preferences is not as strong as some others. Nevertheless, we would like to point out – and we clarify this in the paper – that the relationship is marginally significant at p=0.075 (our cutoff for reporting stars is 0.05). Thus, the negative relationship between academic career preferences and an interest in commercialization is quite consistent throughout our analyses. We now acknowledge this in the discussion of both Table 5 and Table 6.

Your comment also made us think about these issues more generally, and we believe it is worth highlighting that a particular factor (e.g., interest in commercialization) does not have to have the same effect in all regressions to be relevant. Indeed, the various models we estimate (A-E in your list above) are not strictly alternative models to test the exact same effect; rather they include different approaches to look at the same effect (e.g., Table 5 and Table 7) but also models that try to examine different ways in which a factor may matter (e.g., the role of change in levels of X vs. change in coefficients of X; Table 5

vs. Table 6). Nevertheless, your broader point that we should think carefully about the overall patterns that emerge, and consistency between different estimates, is well taken, and reflected in our discussion.

b) Where I am most concerned about inconsistencies is the authors' conclusion that changes in academic labor expectations did NOT affect a PhD student's interest in an academic career.
First, there must be a mistake in Table 5 related to this variable. In columns 2a and 3a, the coefficients are 0.55 and 0.53 respectively, quite far from 1. They are marked and discussed as not significant (no asterisk). But I calculated the t-stats from the odds ratios and their standard errors and they are 2.25 with a p-value of approximately .025 and 2.04 and a p-value of approximately .04, respectively. I'd like the authors to check their calculations and their numbers. Then they need to correct the numbers (if incorrect) or add in asterisk for significance (if correct). Assuming I am correct, it is NOT true that decreases in labor market expectations don't change career interests. They DO change interests. This dovetails with the fact that we do see a significant difference in labor market expectations in 2013 between the two groups "remain interested" and "lose interest" (p=.02 in Table 3) without controls. However, the relationship in levels (what I deemed model C above, Table 5 cols. 1-4) either in 2010 or 2013 do show an insignificant relationship, and with all controls the sign is even wrong (i.e. the more available they think faculty positions are, the less attractive it is). Also, this variable is not at all significant in Table 7 (col 1 all fields), assuming this estimation is correct (see my point 2 above).
I cannot think of a story that reconciles all of these results, but that is not my job. The authors need to think about it and explain it, or highlight it as an anomaly (or check their numbers and find mistakes). They need to report things like the p=.02 for 2013 in Table 3. If the numbers remain as is in Table 5, it seems clear to me that they cannot make a blanket statement that labor market expectations do not affect whether they find academic careers attractive. They thus need to rewrite their introduction and conclusions. (FYI In the to-be-dropped Table 6 Model 5b, high 2010 expectations of faculty positions makes people much less likely to gain interest… another example showing that this model doesn't work.)

Thank you for looking so closely at our results. We apologize for not having clarified the nature of the standard errors reported in the tables. As you may recall, we reported raw coefficients in the initial submission but then changed to reporting odds ratios (relative risk ratios) in response to reviewer 1's request for a more intuitive interpretation of effect sizes. When reporting odds ratios rather than raw coefficients, Stata (the software we use) also adjusts the standard errors accordingly using the delta rule with $se(OR_b) = exp(b)*se(b)$ (see http://www.stata.com/support/faqs/statistics/delta-rule/ and http://www.stata.com/help.cgi?mlogit). As such, the SEs reported in the tables are not the original standard errors but those for the odds ratios (which are smaller than the original SEs for negative coefficients). We now note in our footnotes to regression tables that the SEs are for the odds ratios.

To illustrate the difference, we include below a direct Stata printout of the comparison between the first few estimates of our key model 3a in Table 5 using raw coefficients and odds ratios. As you can see, both models are completely aligned with respect to statistical significance, showing no significant coefficients for labor market expectations.

Raw coefficients:

attr_facres_change	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
1_high_high	(base outcome)					
2_high_low						
prob_facres_chg	-.6311783	.4331076	-1.46	0.145	-1.480054	.217697
prob_est_chg	.6953083	.4882149	1.42	0.154	-.2615754	1.652192
pred_pdreq_facres_chg	-.0266955	.0785126	-0.34	0.734	-.1805773	.1271864
avail_univ_funding_chg	-.055677	.0906179	-0.61	0.539	-.2332847	.1219308
int_basic_chg	-.7454343	.1309148	-5.69	0.000	-1.002023	-.488846
int_applied_chg	-.2203476	.129633	-1.70	0.089	-.4744237	.0337285
int_commercial_chg	.1700593	.0956462	1.78	0.075	-.0174038	.3575224

Using relative risk ratios:

attr_facres_change	RRR	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
1_high_high	(base outcome)					
2_high_low						
prob_facres_chg	.5319646	.2303979	-1.46	0.145	.2276255	1.24321
prob_est_chg	2.004327	.9785423	1.42	0.154	.7698378	5.218406
pred_pdreq_facres_chg	.9736577	.0764444	-0.34	0.734	.8347881	1.135629
avail_univ_funding_chg	.9458446	.0857104	-0.61	0.539	.7919281	1.129676
int_basic_chg	.4745282	.0621228	-5.69	0.000	.3671361	.6133338
int_applied_chg	.8022399	.1039968	-1.70	0.089	.6222435	1.034304
int_commercial_chg	1.185375	.1133766	1.78	0.075	.9827467	1.429783

As you note, Table 3 shows a small significant difference in the *levels* of labor market expectations between the two groups of students in 2013. However, this table also shows that there is no significant difference in the degree to which labor market expectations have *changed* between 2010 and 2013, which is what our regressions focus on. As such, the nonparametric results in Table 3 and the regressions are consistent.

Overall, neither the nonparametric nor the parametric analyses show a significant relationship between changes in labor market expectations and the change in academic interests, telling a consistent story. We are very careful, however, to clarify in the paper that this is by design: Our measure of career preferences was designed to measure preferences (the "supply side") independent of labor market expectation. Thus, we do not claim that labor market expectations play no role in general. Rather, our point is that preferences change independent of labor market factors as well, and the second part of the paper seeks to understand potential drivers of such changes.

4. At the very end, the authors add a discussion on which is the most preferred career based on a 2013 question, without relating it to any of the preferences/expectations. The authors should cut this out. It is on a different topic than the rest of the paper. However, I would suggest that they try using "prefer research faculty" as an alternative dependent variable in a multivariate model. (I'm not clear why they didn't do this to begin with.) If the results are robust, they don't need to report it if they prefer, but could

just say in a footnote that they tried this and that the results are robust. If the results are not result – frankly, that would worry me.

You are correct that this analysis of relative career preferences in 2013 was on a different, albeit very related, topic: This measure reflects preferences in a relative (most preferred career relative to others) rather than absolute sense and does not capture changes over time. We agree that this analysis distracted from our main story and we dropped this section of the paper.

Given that this measure is so different from those used in our analysis of change in absolute career preferences, we do not believe that it can be usefully employed to check the robustness of our main results. That being said, we ran a model using this measure and found that changes in job market factors have no significant coefficients, while changes in interest in basic research and the importance of freedom have a positive coefficient, and changes in the interest in commercialization have a negative coefficient. The other focal variables are not significant (see Model 1 in Table R1 below). It is difficult to compare these results to our main results, however, since they reflect potential effects of independent variables not just on the attractiveness of the faculty career but also of other careers.

5. I take issue with the statements on page 13 that "labor market factors are unlikely to explain why some lose interest in the academic career" because "an increasing awareness of labor market challenges is shared by students who remain interested in an academic career and those who lose interest" as shown in Figure 2a. After all, even if everyone realizes in grad school that fewer academic jobs are available than they originally expected, this new knowledge could affect different people differently. Similarly, on the top of page 12, the authors seem to assume that for labor market expectations to affect some people but not others, it must be true that those who are affected have changed their labor market expectations more than others. Not true! They can change their expectations similarly, but some are nearer to the margin than others. I suggest that the authors simply cut these sentences.

Thank you for this important point. We agree and provide a more accurate interpretation of the results: Given that both groups experience similar changes in labor market explanations, losing interest in academia does not seem to be explained by having experienced larger changes in labor market expectations.

You point out that even if all individuals experience the same change in X, some could respond while others do not, and changes in labor market expectations could thus still explain changes in career preferences. This is an important point and we explored this idea empirically. In our context, people "at the margin" are likely to report academia as attractive (4) rather than extremely attractive (5), and these people might be more easily pushed below the threshold due to a change in market expectations or other factors. To explore this possibility, we distinguish between individuals who in 2010 rated academia a 5 or a 4. As one would expect, a greater share of individuals at the margin (rating of 4 in 2010) lose interest in an academic career relative to those with the strongest preferences (39.55% vs. 21.69%, respectively). We then ran regressions using these two subsamples. For these two groups, the relevant outcome is either "remain interested in academia" or "lose interest in academia", and we estimate a simple logit model with the DV=1 for those who lose interest. We find no significant coefficient on changes in labor market expectations for either sample. Thus, even among PhD students who were on the margin with respect to academic career interests in 2010, changes in the expectations of the availability of faculty positions are not related to changes in academic interest. We believe that this result provides further support for our finding that labor market expectations do not explain the changes in career preferences observed in our sample. Thank you for pointing us in this interesting direction; we now include this analysis as one of the auxiliary analyses in the paper.

6. Several times during the paper, the authors claim to have shown that "the decline in an academic career is not a general phenomenon across all students, but rather a significant divergence between students who remain highly interested and others who lose interest entirely." (page 3; see also pages 7, 9). Very little evidence is shown on this. The only thing I see is the statement on page 7 that "these PhDs show a substantial decline in their attractiveness ratings on the 5 point scale," without defining substantial or showing that the decline is unusually large among this group of people. The authors need either to drop these sentences, or add a proof of this point.

Heterogeneity/divergence in the degree to which students' preferences change is reflected in our primary measure (which distinguishes students by whether and how preferences have changed) and is a key aspect of almost all of our analyses. But we agree that our interpretation of the decline as "losing interest entirely" or "substantial" was not justified enough. These statements were based on the fact that the scale used to capture interest in academia has substantively meaningful anchors ranging from "extremely attractive" to "extremely un-attractive", with a qualitative shift (from attractive to un-attractive) in the middle. We now explain this point more clearly when reporting the descriptive results. We also changed some of the sentences you were concerned about and explicitly use the wording of the scale anchors, which allows readers to decide for themselves how to interpret the magnitude of the observed changes.

7. I would like to be assured (e.g. in a footnote) that all conclusions made remain true if they don't control for "thought about career." The effect in Table 5 says that if you increasingly think about your career near the end of your PhD (and who doesn't?), you are more likely to lose interest in an academic career. I would guess that those who start thinking about their career suddenly learn how hard it is to get a faculty position and that dropping this variable might make the coefficient on change in availability of faculty positions more significant. (I note that people who starting thinking about their career more in between 2010 and 2013 were more likely to lose interest controlling for preferences etc…Table 5 Model 3a.). So if the results are robust, say so in a footnote. But if I am right and dropping this variable does change the paper's results, the authors need to rewrite the results because of this.

Thank you for raising this interesting point. The "thought about career" variable has always intrigued us. As you point out, one would hope everybody thinks about their careers, but our data show significant heterogeneity, and even some late stage students seem to postpone explicit career planning for later (postdoc training, perhaps).

Excluding this variable from our analyses has no significant impact on the featured results – please see Models 2-7 in Table R1 below. We discuss this result in an endnote (#30) in the paper.

Straightforward simple changes:
8. Please add and define the dependent variables in the supplementary table.

We updated this table and added the requested information.

9. Standardize on the word "logistic" or "logit" throughout.

We now use "logit" throughout the paper.

10. The number of observations on page 7 is misleading. You need to add here that you only have 854 people who satisfy the criteria of being early in their grad program in 2010 and late in their program in 2013, and only 825 in regressions. Moreover, you might add the caveat that this subsample is somewhat selective, in that it excludes people who were taking a long time to finish their PhD or those who got through grad school very quickly.

We added the number of cases used for this study (854) on page 7. Our sample does not exclude people who took a long time to finish since we include all respondents who were 1st or 2nd year students in 2010 and still doing a PhD 3 years later, regardless of their graduation date (Although we did ask about their plans; in 2013, 41% of students in our sample expected to graduate that year, 44% expected to graduate in 2014, and 15% expected to graduate in 2015 or later). While some students may already have graduated by the time of our second survey, the number of such cases should be very small since it is rare to complete a PhD in four years or less; the median time to degree for S&E PhDs in research 1 universities was 6.7 years in 2013 (S&E indicators 2016, Table 2-12).

11. Page 7: after "who had thought more about their careers" add "by 2010"

We have revised the paper to include this.

12. Page 11 bottom line: "both groups" needs to be explained.

We have revised the paper to explain these groups.

13. English: page 11 "and their measure" is incorrect English. Replace "a goal of our survey" with "one goal of our survey" page 26 "while they have no significant coefficient in engineering" needs to be "while they have an insignificant coefficient" or "while they do not have a significant coefficient"

Thank you – we made the necessary corrections.

14. Page 18: before "publishing decisions in academic labs" put "students'"

Students may often be the ones making publication decisions but our reading of the literature is that this is not always the case. As such, we kept this issue more open since our main point is that regardless of students' career interests, publishable work produced by students is likely to be published due to the strong career incentives of their advisors/PIs running the lab (whose names are often included on the paper) [1, 2].

15. Page 20 5th line: add "perceived" in front of "ability"

The paper has been revised accordingly.

16. Page 26: You say "but not the other two fields" but only have one other field in the table.

We clarified; the focal sentence referred to the bio/life sciences (Table 7, column 4), the other fields are physics (column 5) and engineering (6).

17. Results would often be clearer if you used percentage points instead of percent in many places, since most of the changes you talk about are in percentage points.

All our results consistently refer to percentage points (although we do not always write this out where it should be intuitive given the context).

18. When you compare coefficients in Table 6 (e.g. Models 2 v. 4), sometimes you add a statistic testing the difference and sometimes you don't. You don't for the coefficients on male in Models 2 and 4 (p.22). Also, on p. 26, the coefficients on subjective ability in Table 7 are not significantly different between Engineering and Physics.

We limit the cross-model formal tests in Table 6 to variables that are also featured in our main analyses as potential explanations for changes in career preferences (i.e., market expectations, preferences, and ability). The main reason to look at such differences is to see whether changes in career preferences may be due to changes in the coefficients of X rather than change in the levels of X (an important point you raised in the last round). We considered expanding these tests to variables that serve primarily as controls but decided against it to avoid confusing readers with results that distract from this primary question. However, for your information, we tested differences between 2010 and 2013 in the coefficients of the gender dummy and the genderXmarried interaction jointly. The $Chi^2(2)$ statistic is 4.20, p=0.12.

19. Page 29/30: Cut out " – just like writings…. when starting the PhD program." It is confusing and unnecessary.

Deleted.

Thank you again for your thorough review and your extremely helpful feedback. We believe that we were able to address all your points and look forward to any additional comments you may have.

References

1. Stephan P. How Economics Shapes Science: Harvard University Press; 2012.
2. Marušić A, Bošnjak L, Jerončić A. A systematic review of research on the meaning, ethics and practices of authorship. PLoS ONE. 2011;6(9):e23477.

Table R1: Regressions for Reviewer

	1	2			3			4	5	6	7
	Most preferred academia 13	including "thought about career"			excluding "thought about career"			with thought 2010	no thought 2010	with thought 2013	no thought 2013
	logit	mlogit			mlogit			ologit	ologit	ologit	ologit
	mostpref_facres13	lose interest	gain interest	over interest	lose interest	gain interest	over interest	attr_facres10	attr_facres10	attr_facres13	attr_facres13
Chg. Availability of faculty position		-0.63	0.44	0.32	-0.65	0.43	0.33				
		(0.43)	(0.62)	(0.49)	(0.43)	(0.62)	(0.49)				
Chg. Availability industry positions		0.7	0.81	0.73	0.66	0.84	0.74				
		(0.49)	(0.95)	(0.49)	(0.47)	(0.92)	(0.49)				
Chg. Number of years of postdoc		-0.03	-0.05	0.02	-0.02	-0.06	0.02				
		(0.08)	(0.15)	(0.12)	(0.08)	(0.15)	(0.11)				
Chg. Availability of research funding		-0.06	-0.08	-0.07	-0.04	-0.09	-0.06				
		(0.09)	(0.18)	(0.10)	(0.09)	(0.19)	(0.10)				
Chg. Basic research		-0.75***	-0.03	-0.23	-0.75***	-0.03	-0.23				
		(0.13)	(0.23)	(0.16)	(0.13)	(0.23)	(0.16)				
Chg. Applied research		-0.22	0.19	-0.25	-0.2	0.18	-0.24				
		(0.13)	(0.38)	(0.18)	(0.13)	(0.38)	(0.18)				
Chg. Commercialization		0.17	-0.34*	-0.09	0.18	-0.36*	-0.09				
		(0.10)	(0.16)	(0.11)	(0.09)	(0.16)	(0.11)				
Chg . Financial income		0.03	-0.24	0.02	0.03	-0.26	0.01				
		(0.16)	(0.26)	(0.16)	(0.16)	(0.27)	(0.16)				
Chg. Freedom		-0.40***	0.52**	-0.39*	-0.39**	0.51**	-0.38*				
		(0.12)	(0.19)	(0.16)	(0.12)	(0.18)	(0.16)				
Chg. Number of pubs		-0.05	-0.02	-0.22*	-0.04	-0.02	-0.22*				
		(0.05)	(0.09)	(0.10)	(0.05)	(0.10)	(0.10)				
Chg. Self-perceived ability		-0.19**	0.33**	0.09	-0.17**	0.33**	0.1				
		(0.07)	(0.12)	(0.08)	(0.07)	(0.12)	(0.08)				
Chg. Thought about career		0.23*	-0.17	0.01							
		(0.09)	(0.23)	(0.13)							
Availability of faculty position 10								-0.16	-0.16		
								(0.34)	(0.34)		
Availability industry positions 10								0	0		
								(0.50)	(0.50)		
Number of years of postdoc 10								0.07	0.07		
								(0.07)	(0.07)		
Availability of research funding 10								0.1	0.1		
								(0.08)	(0.08)		
Basic research 10								0.99***	0.99***		
								(0.11)	(0.11)		
Applied research 10								0.02	0.02		
								(0.20)	(0.20)		
Commercialization 10								-0.13	-0.13		
								(0.08)	(0.08)		
Financial income 10								-0.12	-0.12		
								(0.12)	(0.11)		
Freedom 10								0.75***	0.75***		
								(0.14)	(0.14)		
Number of pubs 10								0.04	0.04		
								(0.05)	(0.05)		
Self-perceived ability 10								0.22***	0.21***		
								(0.05)	(0.05)		
Thought about career 10								-0.06			
								(0.08)			
Availability of faculty position 13	-0.28									-0.23	-0.19
	(0.50)									(0.40)	(0.39)
Availability industry positions 13	-0.46									-0.45	-0.44
	(0.40)									(0.38)	(0.37)
Number of years of postdoc 13	-0.06									-0.08	-0.08
	(0.09)									(0.07)	(0.07)
Availability of research funding 13	0.02									0.12	0.12
	(0.17)									(0.08)	(0.08)
Basic research 13	0.98***									0.90***	0.90***
	(0.21)									(0.09)	(0.10)
Applied research 13	0.1									0.18	0.18
	(0.16)									(0.12)	(0.12)
Commercialization 13	-0.23*									-0.21**	-0.21**
	(0.09)									(0.07)	(0.07)
Financial income 13	-0.26									-0.40**	-0.40**
	(0.18)									(0.14)	(0.14)
Freedom 13	0.72***									0.81***	0.80***
	(0.17)									(0.10)	(0.10)
Number of pubs 13	0.05									0.03	0.03
	(0.04)									(0.03)	(0.03)
Self-perceived ability 13	0.1									0.39***	0.37***
	(0.09)									(0.06)	(0.06)
Thought about career 13	-0.03									-0.14	
	(0.12)									(0.13)	
Controls	incl.	incl.	incl.	incl.	incl	incl.	incl.	incl.	incl.	incl.	incl.
Field fixed effects	incl.	incl.	incl.	incl.	incl.	incl.	incl.	incl.	incl.	incl.	incl.
University fe	incl.	incl.	incl.	incl.	incl.	incl.	incl.	incl.	incl.	incl.	incl.
_cons	-20.89***	-2.20***	-18.78***	-1.95*	-2.10***	-18.86***	-1.96*				
	(1.62)	(0.60)	(1.52)	(0.76)	(0.60)	(1.48)	(0.76)				
N	823	825			825			825	825	825	825

Notes: Raw coefficients; SEs in brackets; * p<0.05, ** p<0.01, *** p<0.001. Variables with "10" are measured in the 2010 survey, variables with "13" are measured in the 2013 survey.

PONE-D-16-34110R1
The declining interest in an academic career

Response to reviewers

Editor

Thank you for submitting your manuscript to PLOS ONE. After careful consideration, we feel that it has merit but does not fully meet PLOS ONE's publication criteria as it currently stands. Therefore, we invite you to submit a revised version of the manuscript that addresses the points raised during the review process.

The reviewer has carefully read the revision and identifies several important issues about presentation of the results that still need to be addressed. None of these should take much time, and I would not need to send a revised version back for another round of reviewing. In addition the reviewer offers a number of suggestions for improvement in the explication of your results.

AUTHORS: Thank you very much for giving us the opportunity to revise this manuscript. We appreciate the feedback from you and the reviewer and have made the requested changes.

In addition, please finalize the information about data availability.

AUTHORS: The confidential nature of the survey and conditions in our approved IRB protocols constrain our ability to make the micro-data publicly available. Given that we asked respondents sensitive questions about their career aspirations, work interests, and subjective ability, we guaranteed them confidential treatment of their data. Moreover, our IRB application states that we will not disclose individual level data or data that could identify individual respondents.

We have considered ways that we might be able to make some data available given our ethical and legal constraints, but concluded that we would not be able to make available most of the variables that are central to this paper, including some of the particularly sensitive questions and individual characteristics that could be used to identify individuals (e.g., subfield, year of PhD program, gender, or university). As such, the data would not allow for replication of our results, especially the regression analyses.

In light of these constraints, we have revised our data availability statement to the following:
"Due to IRB disclosure restrictions and a confidentiality agreement with the respondents, we are unable to make publicly available micro-data for this study (Cornell IRB Protocol #1707007286). Please contact the authors with any questions about the survey or data."

Thank you again for inviting a revision. We hope the revised manuscript meets your expectations and look forward to any additional feedback you may have.

Reviewer 2

I have 5 minor suggestions. I don't need to see the paper again if the authors agree and change the following things:

1. I thank the authors for giving me the stata output so I can see what they did. From this, there are two things that need to be changed in the current version. First, they give the relative risk ratio (rrr) i.e. the ratio of probabilities, and not the odds ratio (the ratio of the odds) and this needs to be changed throughout.

AUTHORS: We now refer to relative risk ratios in all multinomial logit regressions. (For ordered logit regressions, odds ratio is the accurate terminology, as shown in the Stata output).

2. Second, the standard errors given in the rrr analysis cannot be used by readers to do any tests…. although that is not immediately clear to readers. The delta method standard errors are only approximate estimates and if used in this paper give different answers about significance than in their conclusions. To give exact standard errors they would have to give the logit coefficients (not the rrr) which are less intuitive. Therefore, they simply should not report these standard errors. To keep these as rrr's, replace with the 95% confidence intervals (which are not approximations). (Or they may replace with the p-values for the difference from 1. Or include only asterisks in the table, but in an appendix give the logit coefficients and standard errors.) Explain briefly why in the table footnotes.

AUTHORS: We thank you for highlighting this issue. We explored different options and now follow your recommendation to report confidence intervals for the relative risk ratios (and odds ratios) in all tables.

3. What is said about males on page 22 is incorrect. The coefficient on males they discuss ignores the gender interaction terms and as a result only compares single childless males to single childless females. They need to say this. They can also add additional comparisons if they want (e.g. to compare men and women who are both are married with children.)

AUTHORS: We agree that these gender differences are important. As such, we now report comparisons in more detail, account for both main effects and interactions.

4. The title of columns 3-6 of table 7 needs to be changed from "Attractiveness of academic research career" to "Changes in the Attractiveness of academic research careers".

AUTHORS: We revised the column labels accordingly

Here are a few tiny additional suggestions that I believe will improve clarity but if the authors really do not agree, I can live with the current version as is.

5. Fig 1 legend:The graph is not about Science and Engineering, it seems to be about Life Sciences and Engineering. Change legend (or figure).

AUTHORS: Thank you for clarifying this point. We have revised the figure title accordingly.

6. bottom p 3 words "but especially" throws people off unless they have already read the paper... replace with "and"

AUTHORS: We have revised the paper as suggested.

7. p.8 second to last line..... It's unclear who "these PhDs" are.... Rewrite or re-punctuate.

AUTHORS: We revised the text to the following: “students who lose interest in an academic career”

8. p.9 3rd line career should be careers

AUTHORS: We revised the text to “interested in an academic career”

9. p.10. Sentence starting with "The shares of US.... is unclear and incorrect English. Replace with: The difference in the shares of US and foreign PhD students interested in an academic career at the beginning of the PhD is small and only marginally significant...

AUTHORS: We apologize for the grammatical oversight. We have revised the text accordingly.

10. p. 10: Related to my previous review’s point 17: I do not have the confidence you have that all readers are thinking "percentage points" instead of "percent". Really, you overestimate their consciousness of this difference. Pointing it out will be helpful for at least a quarter of readers (who will not be economists no regularly do statistical analyses.)

AUTHORS: Thank you for drawing our attention to a potential point of confusion in our language. We have carefully revised the manuscript to ensure that our language is accurate and to avoid confusion in reporting percentages of the population with percentage changes in shares.

11. p11 bottom line... add "significantly" before "lower"

AUTHORS: We have revised the text accordingly.

12. Bottom 20/top21: I would have added "and vice versa" i.e. students whose preference for research freedom has increased are more likely to gain interest in academic careers as well. Also vice versa in that respondents who feel their research ability has increased are more likely to gain interest.

AUTHORS: To capture the spirit of your comment, we added the following discussion: Although our focus is on students who lose interest in academia rather than those who gain interest, model 3b shows that membership in the latter group is significantly associated with a decreased interest in commercialization, an increased preference for research freedom and increased subjective ability, reinforcing the importance of these variables in explaining changes in academic career interests.

13. p.22 8th line from bottom: I'd replace "may be more important" with "is more important"... you are talking about a very significant relationship (whether causal or not.).

AUTHORS: We have revised the text accordingly.

14. p.26: I'd replace "see previous analysis" with "(table 7 model 3)

AUTHORS: We have revised the text accordingly.

15. p.30 third line: I would add "all" in front of PhDs.

AUTHORS: We have revised the text accordingly.

Thank you again for your extremely helpful feedback throughout the review process. Your comments have significantly shaped this paper, and we believe it can now make an important contribution to the literature.