

**Does Postdoctoral Training Raise the Likelihood of
Pursuing a Career in Research and Development?**

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Introduction

Competition for tenure track positions in academia in the United States is fierce with approximately 16 percent of new U.S.-trained research doctorates in science, engineering and health related fields obtaining tenure or tenure track positions within ten years of graduation (National Center for Science and Engineering Statistics (NCSES). 2021). In many disciplines, postdoctoral training has become a vital rite of passage for scholars wishing to embark upon a career in research and development. Although the number of faculty positions, particularly in the US, is almost at a steady state with little expansion (National Science Foundation, Science & Engineering Indicators, 2021), the number of postdoctoral positions have continued to grow and have spread from the biomedical and physical sciences to engineering and the social sciences (Institute of Medicine, 2014: pg. 1). The time spent in postdocs has also grown (Akerlind, 2005) since before the turn of the century, with the average age of young scholars starting their first academic appointment growing from 34 in 1978 to 38 in 2003 (National Research Council, 2005), partly due to postdocs choosing to take a second postdoc position when they fail to find an academic job at the end of the first (Bonetta, 2009). More recent data show that the average postdoc term is 4-6 years, but varies by discipline (Rockey, 2017).

In spite of their advanced training and accomplishments, *Nature's* first-ever survey of this segment of the scientific workforce found anxiety and doubt about their professional pathways and future prospects (Woolston (2020). The self-directed nature of an academic career is a potential contributor to this concern about the “the continuity of one’s employability and to the quality of subsequent employment” (Colakoglu, 2011: 48).

The concern about future prospects is not unique to the US. The mismatch between the supply and demand for postdocs is a worldwide phenomenon. The overproduction of postdocs relative to the number of available faculty positions contributes to this anxiety, especially among those interested in a career in academia (Netrebin, 2019; van der Weijden et al., 2016). Various surveys of postdocs have also found similar concerns, which can be mitigated by high quality supervision, career counselling and developing strategic plans to help postdocs take control of their own futures in faculty and non-faculty positions (Scaffidi and Berman, 2011).

One of the questions asked in the Institute of Medicine (2014:1) report is: *Is it really necessary for someone to remain in training until their mid-30s before being qualified for his or her chosen career track?* Embedded in this question are a number of sub-questions regarding many facets of the postdoc experience and its contribution to the future success of the postdocs, including its potential costs and benefits, not only to the postdoc, but also to the mentors, colleagues, the home institution, funders, and society at large.

Ideally, postdoctoral training programs should align postdoc career development skills with expected career objectives. Perspective matters in assessing what is considered important for a successful postdoc. Bonetta (2010) found that postdocs considered funding and networking opportunities as the top two factors contributing to their success whereas supervisors found other factors such as mentoring and direction and vision more important with communication skills as the most important factor, at the top of their list of crucial indicators of success. It is important for mentors and universities to provide a clearer picture of career prospects for postdocs outside of academia and to broaden their skillset to be able to compete in those contexts (van der Weijden et al., 2016).

Postdoctoral training is not uniform, nor is the experience of postdocs. But researchers have found general patterns in survey and interview data that suggest changes that could enhance both the postdoc experience and outcomes. Recent studies show that demographic characteristics are relevant to postdoc employment (Wang and Main, 2021) as funders as well as universities attempt to broaden participation by designing programs to enhance postdoc diversity, equity, and inclusion (Rybarczyk, Lerea, Whittington, and Dykstra, 2016).

The likelihood of obtaining an academic appointment in a highly regarded doctoral program diminishes as the number of an applicant's postdoctoral appointments and their duration increases (Nerad and Cerny, 1999; 2002). As universities become more commercialized the rewards of a postdoc become less clear and uncertain. While a postdoc is designed to be an investment in human capital, it is often perceived to be a place holder for young scholars seeking a permanent job in research and development. Although the status of postdocs in terms of salary and benefits is improving, they are caught in a limbo where they are neither students nor faculty. The quality of life of postdocs is not very good given that many postdoc positions in the US lack basic benefits such as health insurance or parental leave for young parents and parents to be (Lee, Williams, and Li, 2017; Yang and Webber 2015). Studies have also found that postdocs do not result in higher salaries ten years into the future, a factor that must be considered when assessing the costs and benefits of a postdoc (Yang and Webber, 2015). Stress, strain, and low job satisfaction are often cited as reasons for not continuing onto an academic career (Dorenkamp, Weiss, 2018; Fitzenberger and Schulze, 2014; Ipsos MORI, 2013).

The National Center for Science and Engineering Statistics (NCSES) as a U.S. principal statistical agency offering data on the Science and Engineering enterprise has long running education and workforce surveys that provide national trend data on the postdoctoral population. The recently developed Early Career Doctorates Survey (ECDS), released in 2021 offers in-depth information about individuals who earned their first doctoral degree (PhD, MD, or equivalent) in the past 10 years and their work at academic institutions and federally funded research and development centers. Unique in scope, the ECDS includes professional and research doctorate holders from all fields trained in the United States and abroad and offers new insights on type of position, scholarly work activities, career advisors and mentors, career aspirations, reasons for choosing a career track with emphasis on research, job satisfaction, and self-assessed work-life balance.

The potential for citation analyses, that capture and connect the evolving research dialogue, to contribute novel perspectives for Science and Technology Indicator (STI) development is widely recognized (Moed, 2017). Information about journal publications, however, is challenging to comprehensively collect in a survey setting. The Web of Science™ captures and connects research profiles. Profiles of research—basic to translational research publications—monitor the evolution of research fields and author networks. The Web of Science (WoS) enables discovery of the structure of multi-level (individual, institutional (by sector), regional, and country) mobility, collaboration, citation, and funding innovation networks. We augmented the NCSES survey data with a dataset obtained by

linking the Survey of Doctorate Recipients and WoS data, which integrates complementary perspectives (human capital, demographic, and research profiles) of U.S. PhD recipient career paths

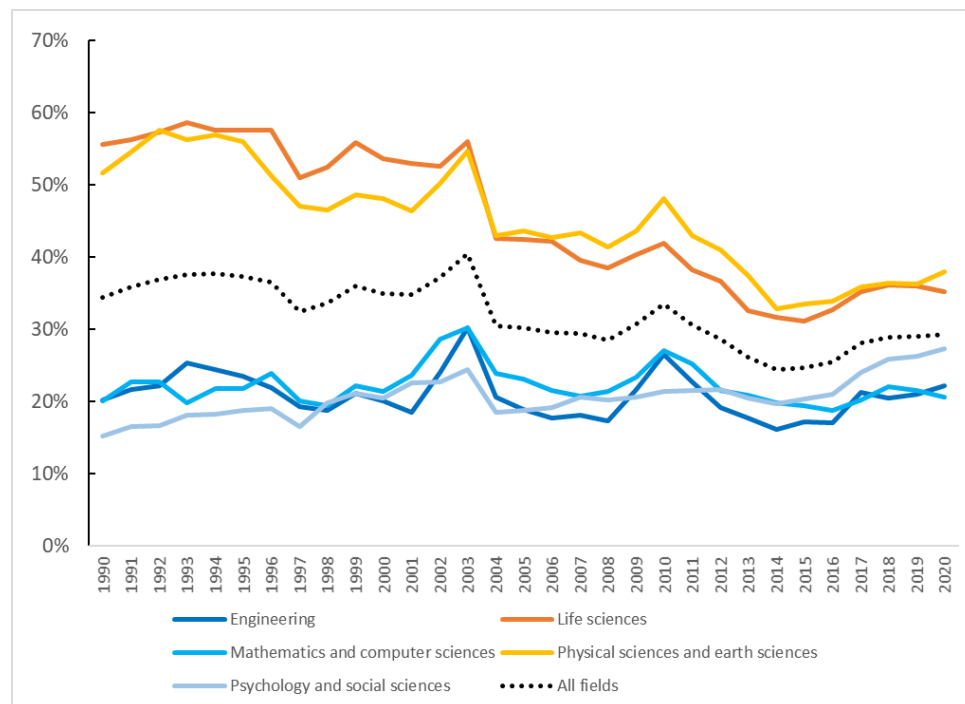
In this paper we assemble a wide range of survey data to provide comprehensive summaries of the postdoctoral population including recent trends in population size, funding sources and mechanisms, demographics, work experiences, and career paths of individuals. We developed a simple statistical model to examine the decision to pursue a postdoc and the role of publications and other factors that could inform our understanding of a career in research and development within or outside academia.

Methods and Results

A. Doctoral and postdoctoral trends

Data from the Survey of Earned Doctorates (SED) cohorts form FY 2006-2013 show that of the U.S.-trained STEM research PhDs., nearly 60 percent reported having definite employment arrangements including returning to, or continuing in, predoctoral employment, or signed contract or commitment for a postdoc or other work at the time of graduation. The remaining 40 percent reported indefinite post-graduation plans including negotiating or seeking a position, enrolling in a full-time degree program, no plan to work or study, or having any other commitment. Of those with a post-graduation plan, the proportion with definite postdoc commitments varies by field of study ranging from as high as 40 percent for the Biological and Physical Sciences to much lower rates (~21%) for other fields (Figure 1.) The figure also shows that even for fields where fresh doctorates have sought postdoc positions, the numbers are falling from high in the 50 to 60 percent range in the 1990s and early 2000s to under 40 percent in 2020.

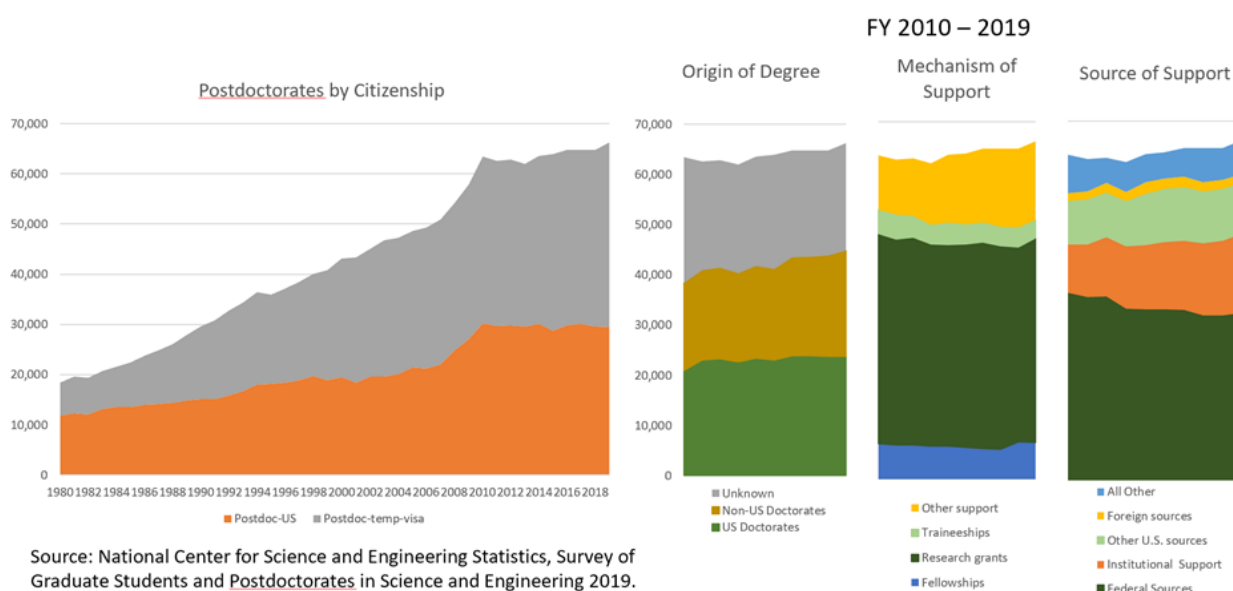
Figure 1. Definite postdoc employment plan post-graduation



Source: National Center for Science and Engineering Statistics, Survey of Earned Doctorates 1990 - 2020

The Survey of Graduate Students and Postdoctorates in Science and Engineering (GSS) provides data on the total number of postdocs working in the U.S. academic sector (Figure 2). Data from 2010–2019 show that after rapid growth, fueled in part by the growth of non-US citizens, for about 30 years since 1980 in the size of postdoc population, which has leveled off at around 63,000 since 2010. The current postdoc population is almost evenly split between US citizens and foreign nationals. At least one third of postdocs obtained their doctorate from a non-U.S. institution. GSS collects aggregate data from administrators, not individuals, which is why many of the *Origin of Degree* information is reported as unknown. Federal funding is the largest primary *Source of Support* with research grant as the dominant *Mechanism of Support* (Figure 2).

FIGURE 2. Trends of postdoctorates – Survey of Graduate Students and Postdoctorates in Science and Engineering



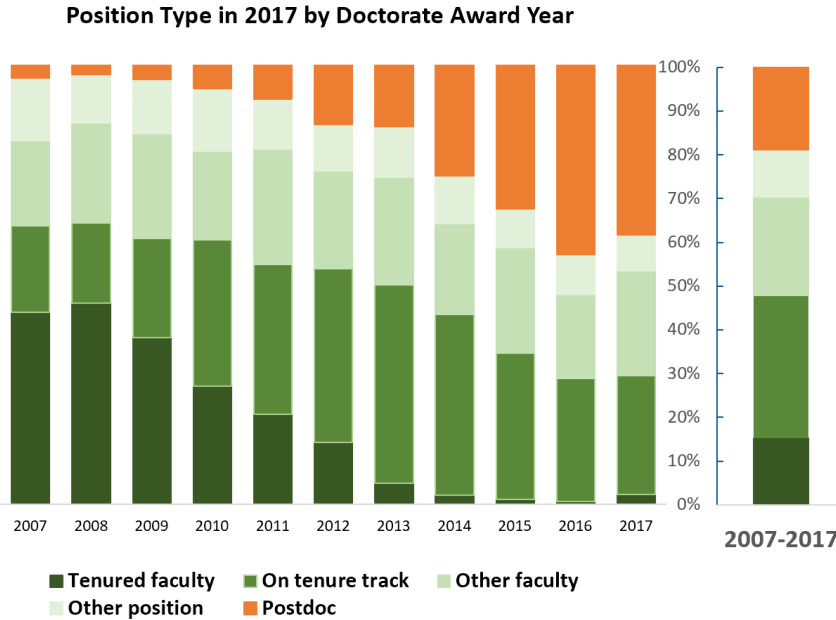
B. Trends among early doctorates

The future for doctoral students towards the end of their degree programs is full of opportunity and uncertainty. Around the middle of the last century, when universities were growing, academic jobs were relatively easy to come by. While the academic market is no longer growing, the demand for doctorates in other parts of the economy has grown, providing more opportunities for doctoral students.

Among early career doctorates working at academic institutions during the week of October 1st, 2017, 70 percent were in faculty positions while 19 percent were postdocs and 11 percent in all other positions. Tenured faculty or tenure-track faculty accounted for 48 percent.

Early career doctorates were more likely to hold postdoc positions the closer they are to their doctorate award year. Almost 83 percent of postdocs earned their doctorate between 2013–2017 while 93 percent of tenured faculty earned their doctorate between 2007 – 2012 (Figure 3.)

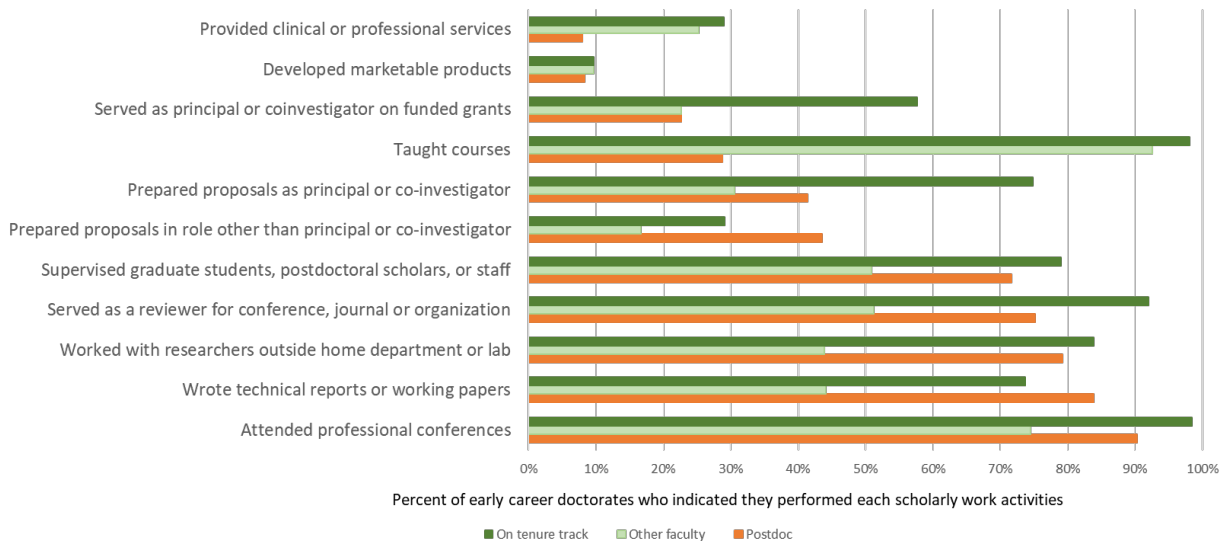
Figure 3. Position type of early career doctorates in 2017 by doctorate award year.



Source: National Center for Science and Engineering Statistics, Early Career Doctorates Survey 2017

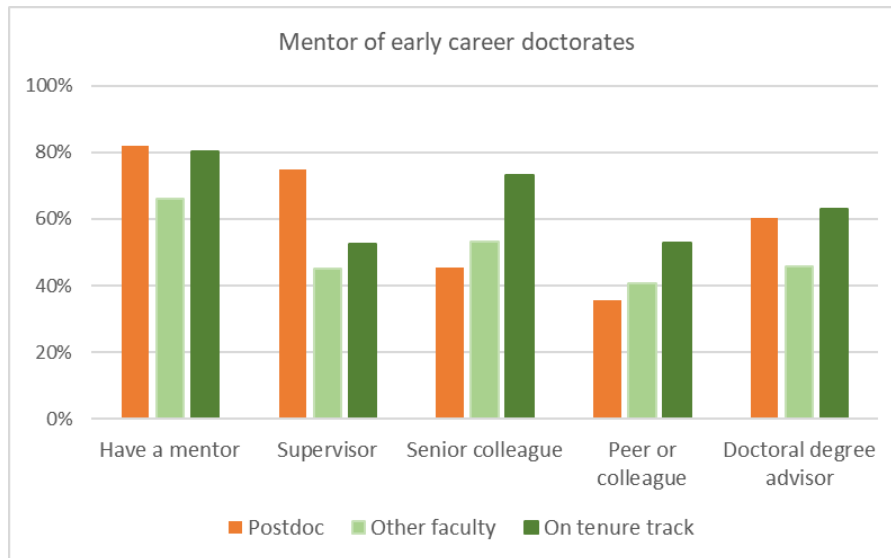
When compared to non-postdocs in academia for a wide range of scholarly activities, postdocs were more likely to work with researchers outside their home department or lab, however, they were less likely to serve as a principal investigator or co-investigator on funded grants or served as the lead principal investigator or co-investigator in preparing proposals. Also, a much lower proportion of postdocs taught courses (Figure 4.)

Figure 4. Scholarly work activities of early career doctorates



Source: National Center for Science and Engineering Statistics, Early Career Doctorates Survey 2017

Figure 5. Early career doctorates who reported having a mentor and individuals who they considered to be their mentor.



Source: National Center for Science and Engineering Statistics, Early Career Doctorates Survey 2017

Mentors of early career doctorates held a range of titles from supervisor to senior colleague to peer or colleague to doctoral degree advisor. Among early career doctorates who responded positively to having a mentor, a similar percentage of postdocs (82%) and tenured-track faculty (80%) reported having a mentor compared with 66% of other faculty (Figure 5).

When it came to juggling between professional and personal life balance, a similar trend was observed among early career doctorates across all four factors (able to manage demand of position, work schedule allowed maintenance of quality of life, supervisor understood relationship between personal and professional responsibilities, and demands at home have slowed progress of professional activities). However, a greater proportion of postdocs (76%) reported supervisor understood relationship between personal and professional responsibilities than tenured-track faculty (64%) and other faculty (62%) (Figure 6).

Figure 6. Work-life balance of early career doctorates covering 2013 to 2017 doctorate award years

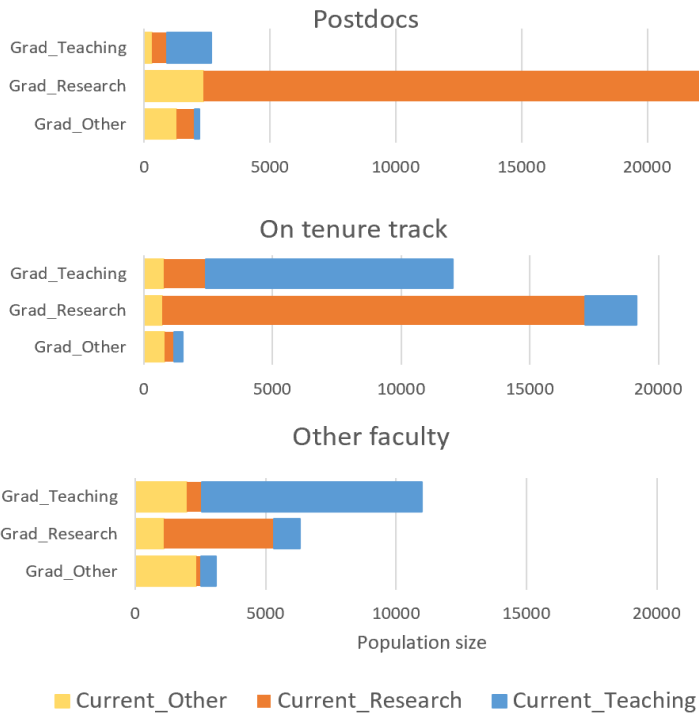


Source: National Center for Science and Engineering Statistics, Survey of Earned Doctorates 1990 - 2020

Career aspiration in terms of career track most interested in pursuing for the next 10 years is reported for the time when earning their doctorate and the time of completing the survey in 2017 in the ECDS. Overall 55 percent of early career doctorates in postdoc, tenured-track faculty and other faculty positions indicated interest in pursuing faculty track position with an emphasis in research followed by an emphasis in teaching with 31 percent and other track with 14 percent (Figure 7). Among postdocs, 83 percent selected faculty track position with an emphasis on research at the time of they completed the survey in 2017 compared with 59 percent for tenure-track faculty and 31 percent for other faculty. Fifty-four percent of those in other faculty positions selected faculty track position with an emphasis on teaching as the career track they most interested in pursuing for the next 10 years compared with 10 percent for postdocs and 37 percent for tenured-track faculty.

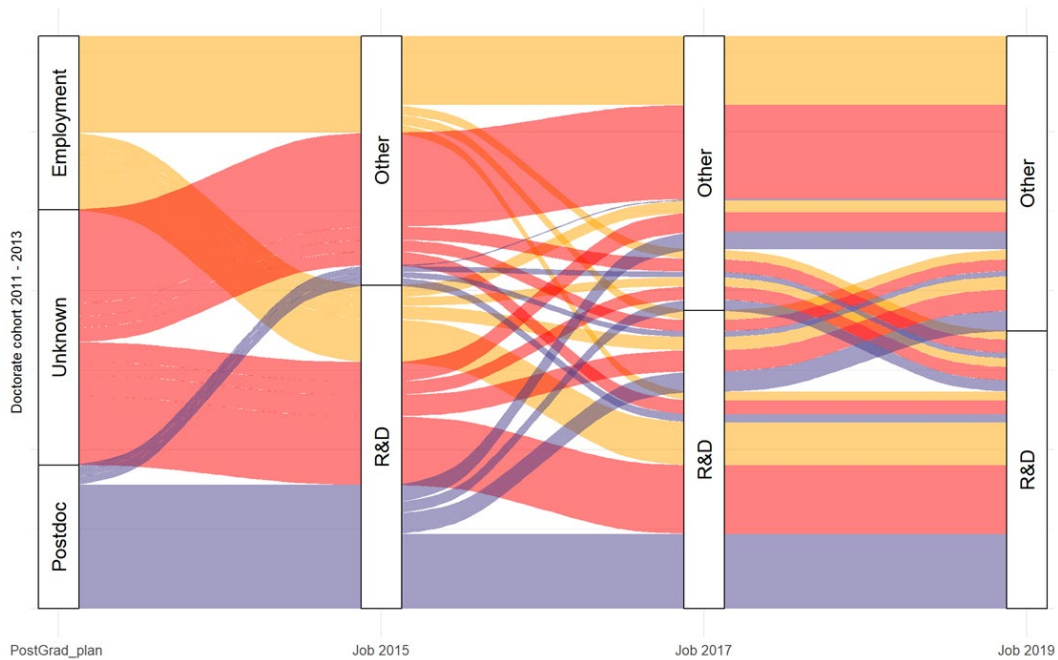
Longitudinal data from the Survey of Doctorates Recipients (SDR) track the employment outcome of U.S.-trained doctorate holders. When linked to the employment commitment immediately post-graduation show a similar picture that early indicator is strongly associated with outcome in terms of performing R&D in future jobs (Figure 8). For the graduating cohort (FY 2011-2013), among those who started out in postdoc, 69 percent reported performing R&D as primary work activities in 2019, and 52% reported holding R&D jobs continuously from 2015 – 2019.

Figure 7. Current career track most interested in pursuing in the next 10 years of early career doctorates



Source: National Center for Science and Engineering Statistics, Early Career Doctorates Survey 2017

Figure 8. Employment commitment at graduation as an early indicator of employment outcome – first seven years post-graduation



Source: National Center for Science and Engineering Statistics, Survey of Doctorates Recipients 2015, 2017, and 2019

C. Career in research and development

The complementary integration of NCSES survey data, including education surveys, work force surveys, and a new survey on early career doctorates, and Web of Science bibliometric data linked to surveys, provides an overview of size, funding source and mechanism, demographics, and other tangible factors composing the ecosystem of postdoctoral positions in academia. The recently released Early Career Doctorates Survey (ECDS) further explores aspects such as type of position, scholarly worked activities, career advisors and mentors, career aspiration, reasons for choosing a career track with emphasis on research, job satisfaction, and self-assessed work-life balance.

Employment outcomes reported in the surveys enriched by linking scientific publication profiles to survey respondents, provide rich source for exploring different aspects defining a career in R&D and determinants of pursuing and succeeding in a research career. Logistic regression models were developed to investigate factors influencing propensity of committing to a postdoctoral position immediately after graduation, and the association between this early indicator and the likelihood of sustaining a research career.

Factors included in the regression analysis can be organized into three groups: (1) background and demographics including sex, race/ethnicity, citizenship, marital status, parental education, living with young children, and type of undergraduate institution; (2) graduate training and support including source of graduate support, level of graduate debt, Carnegie classification of doctorate awarding institution, doctoral field of study, indicator of authoring publications during graduate school; (3) Post-graduation plan and scientific publication output including location intend to live, employment plan, indicators of publishing at least one time, authoring at least one publication with international coauthors, authoring at least one publication on a high impact journal. The post-PhD publication indicators are calculated for publications appeared during the first 5 years and during the 6-10 years post-graduation.

Three sets of models were developed. The first set examined factors associated with the early decision of making a postdoc commitment among graduates reported definite post-graduation plan. The second set of logistic regression models examined the propensity of having R&D as primary work activities for jobs held seven and twelve years after graduation. The third set of models investigated a subsample of those who had definite commitment in academia immediately post-graduation. In the third set of models, those started in postdoc are compared to those started in non-postdoc position in academia, and outcomes examined including primary work activities in R&D, remained employed in academia seven years post-doctorate, obtained tenure or on tenure track, supported by Federal contracts grants, and held a job closely related to doctorate field.

Summary of findings

Results of the main models are summarized in Table 1. Field of study is by far the most important factor related to early postdoc commitment. Type of primary source of financial support comes in second, and pre-doctorate publication indicators and a few demographic variables are also highly significant. Committing to a postdoc immediately after graduation is an early indicator of pursuing a research career and is also confirmed to be a strong factor associated with higher propensity of performing R&D in future jobs. Scientific publication output appeared to be a dominant factor in all main models. Post-PhD publication output indicators are related to the pre-PhD publication indicators and are replacing them as prime factors associated with outcomes at least seven years post-graduation.

Table 1. Estimated odds ratio from main logistic regression models predicting outcomes of postdoc plan, primary work activities in R&D, employed in academia, or obtaining tenured or tenure-track position.

**Preliminary Draft
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Categorical factor (specified level versus reference level)	Outcome indicator				
	<i>Commit to postdoc immediately post-graduation</i>	<i>Working in R&D 7 years post-graduation</i>	<i>Working in R&D 12 years post-graduation</i>	<i>Remain employed in Academia</i>	<i>Tenured or on tenure-track</i>
Gender (vs Male)					
Female		0.776*	0.750*		0.824
Race/Ethnicity (vs white, non-Hispanic)					
Asian		1.353*	1.415*	0.699	0.606
Black, Hispanic, and other races					
Citizenship at doctorate time (vs U.S. citizen)					
Permanent resident					
Temporary visa holder			1.569		
Unknown					
Marital status (vs not married)					
Married	0.892				
Other					1.721
Dependent age 5 or younger (vs none)					
Have at least one					
Dependent age 6-18 (vs none)					
Have at least one	0.486*				
Parental education (vs bachelor's or higher)					
High school or less	0.836			1.495	
Other	0.835				
Field of Degree (vs Health)					
Biological, agricultural, and life sciences	3.635*			0.347*	0.408
Computer and information sciences	0.506*	0.638*	0.567	0.303*	
Mathematics and Statistics	1.363		0.685		
Physical sciences	2.818*			0.387*	0.456
Psychology	2.246*	0.721*		0.514*	
Social sciences	0.538*				1.651
Engineering	0.742*			0.374*	
Graduate cohort (vs 2006-2008)					
2011-2013	1.131				
Bachelor's institution (vs Baccalaureate colleges)					
Research University (RU/VH)	1.163	1.218		0.66	
Research University (RU/H)				0.643	
Master's colleges and universities					
Other	1.248	1.575			
PhD institution (vs highest research RU/VH)					
Research University (RU/H)	0.747*	0.700*			
Other		0.875*	0.757		
Primary source of graduate support (vs Research assistantship)					

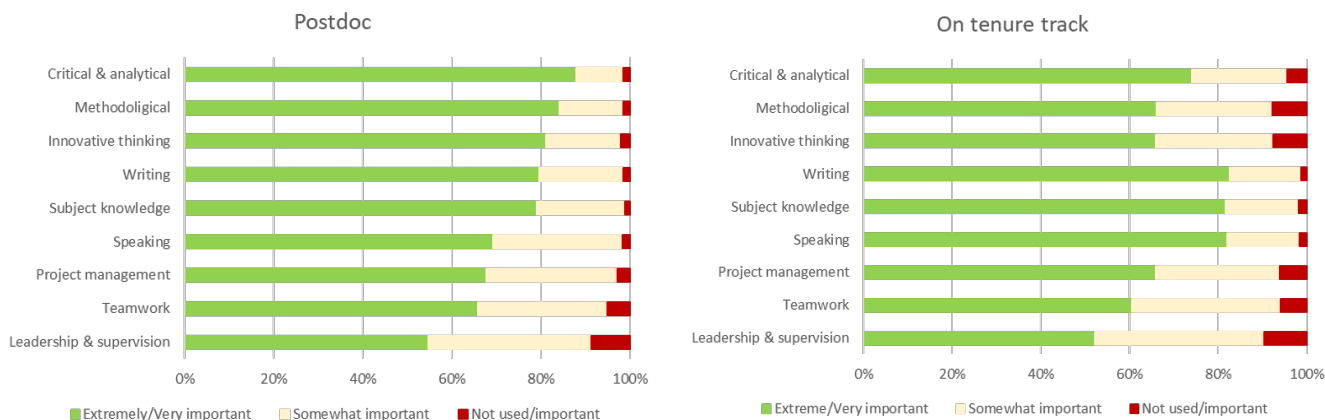
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Fellowship					1.320*
Teaching assistantship	0.752*	0.688*	0.738		
Personal source/Loan	0.346*	0.675*	0.599		
Other	0.337*				0.600*
Graduate education debt (vs none)					
Have debt					
Unknown		1,378			
Pre-PhD publication, years -4-0 (vs none)					
At least one	1.390*				
Pre-PhD publication with international coauthors (vs none)					
At least one	1.251*				
Pre-PhD high impact publication (vs none)					
At least one	1.340*				
Postgraduation commitment (vs non-postdoc employment)					
Postdoc		1.412*	1.311	0.311*	0.430*
Unknown					
Intending to stay in the U.S. (vs U.S.)					
Non-U.S.		0.778	0.696		
Unknown					
Post-PhD publication, years 1-5 (vs none)					
At least one		1.409*		2.485*	2.877*
Post-PhD publication with international coauthor, years 1-5(vs none)					
At least one				1.404	1.243
Pre-PhD high impact publication, years 1-5 (vs none)					
At least one		1.690*			
Post-PhD publication, years 6-10 (vs none)					
At least one			1.539*		
Post-PhD publication with international coauthors, years 6-10(vs none)					
At least one			1.473*		
Pre-PhD high impact publication, years 6-10 (vs none)					
At least one			1.654*		
Sample size	12,296	8,366	5,927	2,707	2,707
Sample description	All graduates with definite post-graduation plan, FY 2006-2008, and 2011-2013	All graduates from FY 2011-2013 and responded to SDR 2019	All graduates from FY 2006-2008 and responded to SDR 2019	All graduates with definite plan to work in academia immediately post-PhD, FY 2011-2013	All graduates with definite plan to work in academia immediately post-PhD, FY 2011-2013

Notes: 1. Not all factors are applicable to all models and shaded cells indicating factors are excluded. 2. All odds ratios are significant at the 0.05 level, and those reached 0.0001 level are marked with *.

However, the positive association between early postdoc commitment and a continued career in R&D took an interesting reversal in the last two models in Table 1. Those starting in academia with a postdoc were less likely to remain employed in academia or obtain tenure or on tenure track when compared to those starting with a non-postdoc position. The SDR data also showed a sizeable proportion of postdocs who aspired to pursue a research position in academia eventually moved to jobs in other sectors or shifted work activities away from R&D.

Figure 9. Importance of skills to current position



Source: National Center for Science and Engineering Statistics, Early Career Doctorates Survey 2017

Studies (Ålund *et al.*, 2020) have suggested misalignment of the skills and credentials prioritized in postdoc positions and the contemporary job market. The ECDS reports on how important a certain skill is for meeting supervisor’s expectations in respondent’s current position for a set of skills. Among new graduates within five years post-PhD, differences can be seen between those held postdoc and those on tenure track (Figure 9.)

POLICY INSIGHTS

Our analysis finds that having published while in the doctoral program is positively related to better prospects for a career in research and development. In many respects such findings lend further credence to common, but often unsubstantiated beliefs regarding the habits picked up in graduate school and early in one’s career stay with people throughout their careers. In this paper, we have attempted to bring evidence to understand, explain, and perhaps predict how doctoral and postdoctoral experiences influence future success of young scholars in research and development.

We learned that although the postdoctoral experience is not as well examined as that of doctoral students or early careers of faculty, there is a considerable amount of data on the postdoctoral experience. There is also information about research output, to be obtained from publications, citations, patents and other outputs of the research and development enterprise. Some surveys include information on work-life balance and other non-work-related aspects of the postdoctoral experience. Unfortunately, these data are dispersed across many databases including surveys such as those we have drawn upon in this paper. To properly examine this aspect of the research and development workforce, the first step is to make it easier to link the data from these databases to enhance the ability of researcher and students of capital to conduct their analyses systematically and rigorously.

We have learned that there is no such thing as *the* postdoctoral experience. It is diverse and heterogeneous; it varies by discipline and across universities. Although having published in a scholarly journal while in graduate school does seem to be related to future success it is not the only indicator of success. However, waiting to have publications before applying for a postdoc position might be counterproductive, because good postdoc positions get filled quickly and might not be available later, regardless of the quality of the publications (Bonetta, 2011). While publications matter in transitioning from postdocs to a career in research and development, postdocs report that a combination of publications and teaching experience is more beneficial for obtaining a tenure track or faculty position (Woolston, 2020).

All these factors point to the fact that funders such the National Science Foundation already know. Mentors play a major role in this experience as does the funding support in graduate school. That is, a good mentorship plan is important and that there are many more opportunities, other than academia postdocs, but they need to be made aware of those opportunities and be given the right set of tools to be able to succeed in environments other than the academy.

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