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Isolated in the Lab: Examining Dissatisfaction with Postdoctoral Appointments

Dissatisfaction with postdoctoral appointments is associated with demographics, career goals, types of research, postdoc-advisor interaction, and program quality. Rather than a simple inverse relationship to dissatisfaction, the effect of program quality depends on the postdoc's autonomy to shape a research project, interaction with an advisor, and the advisor's commercialization-related activities.

Keywords: postdoctoral appointments, early career researchers, satisfaction, commercialization, mentoring

The postdoctoral appointment (postdoc) is an intermediate career stage between completing the doctoral degree and gaining long-term employment. A successful postdoc appointment with a prominent advisor at a prestigious institution can have a high payoff in the cumulative advantage that characterizes scientific careers (Merton, 1968; Su, 2011). Many postdocs, however, move through multiple short-term contracts with few employment benefits and uncertain career trajectories in an *ad hoc* labor market with limited access to information and little standardization of expectations (Wei, Levin, & Sabik, 2012). The timing

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of the postdoc during the early career—often a time of peak creativity—may reduce overall scientific productivity (Stephan & Ma, 2005; Zubieta, 2009). Moreover, dissatisfaction with the postdoc experience contributes to many scientists' decisions to change career, not realizing the full returns to either personal or societal investments. Stephan & Ma (2005) and Butz et al. (2003) argue that the prospect of a postdoc deters many of the most talented students, especially U.S.-born men, from pursuing careers in science. The postdoc has also been identified as a juncture where many women exit or reduce their commitment to the scientific workforce (Martinez et al., 2007).

Despite concerns over the future scientific workforce, there has been little empirical investigation of the individual postdoc experience and the factors that influence dissatisfaction with postdoc appointments. Addressing these concerns is important to the overall functioning of the scientific enterprise and has implications for individual careers. In summarizing results of the 2003 Sigma Xi Postdoc Survey, Davis (2005) paraphrased Tolstoy and observed that each unsatisfactory postdoc experience was unhappy in its own way. Davis' explanation emphasizes individual characteristics rather than institutional or systemic factors. Understanding sources of dissatisfaction with the postdoc experience is a first step towards improving the situation.

This article provides new evidence based on a large, recent survey of postdocs. The current study finds that the probability that an individual postdoc will be dissatisfied is a function of individual demographic characteristics and expectations about career goals coupled with experiential characteristics such as types of research, postdoc-advisor interaction, and program quality. This article presents results of an ordered Probit regression based on survey data from 1,137 postdocs. Rather than finding a simple inverse relationship between program quality and dissatisfaction, the relationship is mediated by the postdoc's autonomy to shape a research project, frequency of interaction with a faculty advisor, and the advisor's commercialization-related activities. The article concludes with a discussion of results, policy implications, and directions for future research.

Dissatisfaction Among Postdocs

To identify potential causes of dissatisfaction, the job satisfaction literature has long emphasized the need to examine individual and environmental factors (Seashore & Taber, 1975). While a review of the extensive job satisfaction literature is beyond the scope of this article, we frame our study around select well-established models and their recent application to a population—STEM faculty in major research

universities—similar to the population in the current study (Bozeman & Gaughan, 2011). We also summarize job satisfaction research and issues specific to the postdoctoral career stage.

Seashore and Taber describe measurement of job satisfaction as “a result of fit between need and need fulfillment” (p. 339), emphasizing the importance of both individual and environmental factors in determining satisfaction. “Prevailing conceptions view job satisfaction as a joint product of characteristics of job and job environment on the one hand, and the characteristics of the person on the other, with the effective set of relevant job characteristics and personal characteristics depending upon unspecified combinations and interactions between them” (p. 340). Bozeman and Gaughan (2011) apply a similar model, examining the contributions of individual, work, and institutional characteristics to the job satisfaction of STEM faculty.

At the individual level, Seashore and Taber (1975) model the correlates of job satisfaction as demographics, stable personality traits, abilities, and situational aspects of personality, such as motivations and preferences. At the environmental level, they include characteristics of the job and job environment, the organizational environment, and the macroeconomic and political context. The organizational behavior literature on person-job and person-organization fit provides a framework for understanding job satisfaction as the result of congruence between individual and environmental characteristics, rather than being purely determined by the characteristics themselves (Edwards, 1991; Kristof-Brown, Zimmerman, & Johnson, 2005).

Hackman and Oldham (1976) provide a model of the job characteristics relevant to satisfaction, including skill variety, task identity, task significance, autonomy, and feedback. In their meta-analysis of the influence of job characteristics on job satisfaction, Loher, Noe, Moeller, and Fitzgerald (1985) found the influence of job characteristics on satisfaction to be especially strong for workers high in growth need strength. Because the postdoc appointment is an explicitly developmental position, growth need strength is likely to be high among postdocs.

Economists contributing to the job satisfaction literature have focused primarily on the role of earnings, identifying the importance of comparison groups (Clark & Oswald, 1996) and expectations (Hamer-mesh, 2000). Postdocs’ satisfaction may depend on whether they compare themselves to other U.S. postdocs, doctorate recipients in foreign countries, or peers who entered lucrative fields, such as finance, with a bachelor’s or master’s degree.

In the specific context of STEM faculty, Bozeman and Gaughan (2011) evaluate the effects of gender, race, marriage, and field at the individual level; tenure, work composition, colleague interactions, and

pay perception at the job level; and research center affiliation and industry collaboration at the institutional level.

The stresses facing postdocs are a frequent topic in the popular scientific press, with headlines like “Career Transitions: Panel Throws Lifeline to Struggling Postdocs,” “Postdoc Trail: Long and Filled With Pitfalls,” “The Postdoc’s Plight,” and “A Pressure Cooker for Postdocs?” (Survey Sciences Group, 2008). In extreme cases, postdocs have been involved in workplace-related violence as victims (The Associated Press, 2010) or alleged perpetrators (Moran, 2008) or have succumbed to psychological stress, even to the point of suicide (Krupnick, 2011; Smaglik, 2006).

Earlier surveys have quantified dissatisfaction among postdocs and yielded a wide range of results (see Table 1). While direct comparisons are limited by differences in samples and measurement approaches across these surveys, levels of satisfaction appear to have varied significantly over time. Reported levels of satisfaction range from nearly universal satisfaction (Curtis & National Research Council [NRC], 1969) to widespread dissatisfaction (NRC, 1981) to a more moderate 22% dissatisfaction in the Sigma Xi survey (Davis, 2009). Global satisfaction measures such as the one used by Sigma Xi (and by our study) tend to understate the level of dissatisfaction (Oshagbemi, 1999). The Sigma Xi sample included postdocs in a broad range of fields, including social sciences and humanities, and a broad range of settings, including industry and government labs. Postdocs in the major research universities included in our study may be less likely to be dissatisfied.

The following section reviews prior research on postdocs, which suggests several factors likely to be associated with postdocs’ dissatisfaction. Prior research on each of these factors is summarized in turn.

Research

Research is central to the postdoc experience. Scientists are thought to be motivated by an intrinsic interest in extending the boundaries of knowledge (Anderson, Ronning, De Vries, & Martinson, 2010; Merton, 1973). One important difference between careers of faculty at research universities and those of researchers in other settings is their greater opportunity to engage in basic research (Agarwal & Ohyama, 2013; Sauermann & Stephan, 2012). Postdocs typically are interested in pursuing faculty research careers and postdoc appointments in academic settings and have the expectation to engage in basic research.

Of course, scientists’ levels of interest in types of research vary (Roach & Sauermann, 2010). Some scientists are interested in more applied research and development activities. A mismatch between a

TABLE 1
Selected Published Surveys Measuring Postdoc Satisfaction in the United States

Survey	Data Year	Sample	Measure	Findings
Sigma Xi Postdoc Survey (Davis, 2005)	2003	Postdocs in academic and nonacademic organizations in science, engineering, social science, and humanities fields	5-point Likert scale	22% of postdocs expressed dissatisfaction.
Survey of Doctorate Recipients (Corley & Sabharwal, 2007)	2001	Postdocs who earned PhDs in the US	Rated 9 aspects of postdoc experience on 5-point Likert scale, very dissatisfied to very satisfied	Foreign-born scientists less satisfied on 5 criteria. Postdocs satisfied with intrinsic motivation, somewhat dissatisfied with extrinsic motivation.
Survey of Scientists and Engineers (National Research Council, 1981)	1979	Postdocs in the biosciences who had received their PhDs in 1972 and 1978	Qualitative comments	75% of 1972 graduates described postdoc appointments as highly rewarding. Approximately 75% of 1978 graduates were dissatisfied.
Postdoctoral Experience Questionnaire (Curtis & National Research Council, 1969)	1967	Academic scientists	Rated 8 aspects of postdoc experience on 3-point scale unsatisfactory to highly satisfactory	Only opportunity to teach was rated less than satisfactory.

postdoc's interest and the postdoc's current research may indicate poor fit, and a potential source of dissatisfaction (Edwards, 1991; Kristof-Brown, Zimmerman, & Johnson, 2005).

Career Goals

Postdocs' motivations for taking the appointment often center on pursuit of an academic research career and a desire to further develop or signal their level of human capital, while being constrained by personal, institutional, and labor market circumstances (Miller, 2012). Postdoc appointments are most closely aligned with career goals in academic research, since they are practically required in many fields for a faculty appointment at a research university (Nolan, Buckner, Kuck, & Marzabadi, 2004; Rudd, Picciano, Nerad, & Cerny, 2010). Postdocs who intend to pursue faculty research careers and those with a strong interest in basic research may therefore be expected to be more satisfied with their appointments compared to postdocs with other career goals.

Postdocs' dissatisfaction may also be influenced by the extent to which their appointment supports their career goals. In fact, 85% of the postdocs in our sample reported that skills development was an important factor in taking their current appointment. However, 21% of the sample reported taking their current postdoc appointment because no other job was available (reasons were not mutually exclusive).

With respect to both research and career goals, Seashore and Taber's (1975) emphasis on fit and need fulfillment as correlates of satisfaction seem especially relevant to the postdoc experience.

Postdoc-Advisor Interaction

Another factor believed to influence satisfaction with postdoc appointments is the quality of structured oversight provided (Davis, 2009; Scaffidi & Berman, 2011). Davis's (2005) analysis of the Sigma Xi survey found structured oversight, defined as the postdoc's relationships with a lab and faculty advisor, to be more influential than compensation and benefits in determining postdoc satisfaction. Postdocs who are dissatisfied might be expected to lack structured oversight, since not all postdoc advisors embrace the role of mentor (Fetzer, 2008). Alternatively, dissatisfied postdocs might be micromanaged in a way that does not facilitate the transition to an independent research career (Laudel & Gläser, 2008). The National Science Foundation (NSF) recognized the importance of this relationship by introducing a mandate in 2009 requiring principal investigators to include a mentoring plan for postdocs funded through their grants (NSF, 2009). While prior research on postdocs has found benefits from structured oversight, the "paradox of

autonomy” implies that such oversight should balance direction and involvement (Trevelyan, 2001).

Cumulative advantage, in which those who have an initial advantage tend to accumulate future advantages, has long been identified as a characteristic of scientific careers (Merton, 1968). Thus, postdocs are likely to seek to work with the advisors with the highest research ability and gain the most from those associations. Good mentoring relationships with highly regarded researchers are expected to be inversely related to dissatisfaction in postdocs.

Demographics

Prior studies have found older doctorate recipients less likely to take postdoc appointments, possibly due to financial obligations (McGinnis, Allison, & Long, 1981; Recotillet, 2007; Zumeta 1985). Financial concerns may also be greater for married postdocs or those with children, and effects of family obligations have been found to differ for men and women (Helbing, Verhoef, & Wellington, 1998a; Martinez et al., 2007; NRC, 1981). Akerlind (2005) finds that satisfaction declines as scientists spend more years as postdocs or take multiple appointments. This effect may be independent of age, as postdocs feel less valued the longer they remain in an appointment (Helbing, Verhoef, & Wellington, 1998b). Although decreasing satisfaction over time as a postdoc has been a consistent finding, it may potentially be countered by attrition of postdocs who are especially dissatisfied.

Prior work has demonstrated that parenthood plays a different role in the academic careers of men and women (Mason & Goulden, 2004). Qualitative and survey research on postdocs has previously found family to be a greater barrier to women’s careers (Martinez et al., 2007). While prior research has identified no clear direct relationship between gender and satisfaction as a postdoc, gender may have an effect mediated by parental or marital status. Gender and discipline were related to job satisfaction in science faculty (Sabharwal & Corley, 2009). In the sciences and health disciplines, men were less satisfied than women, but only after controlling for demographic, institutional, career and productivity variables. Because the unconditional mean satisfaction was higher for male faculty, they interpreted this finding as consistent with women having lower job quality expectations.

Earlier studies had found that several demographic characteristics were related to satisfaction as a postdoc. There is concern that native-born males may be leaving the scientific workforce, “crowded out” by immigrants or lured away by higher earnings in other careers, especially finance (Black & Stephan, 2010). If U.S.-born males tend to leave sci-

ence for better opportunities, perhaps they are more likely to be dissatisfied as postdocs. However, Corley & Sabharwal (2007) found that non-citizen postdocs were less satisfied. Thus, the direction of the expected relationship between citizenship and satisfaction is ambiguous, especially keeping in mind the potential for higher attrition as those who would be dissatisfied may select out prior to the postdoc.

Program Quality

The prestige of a postdoc program has been found to be associated with the prestige of subsequent faculty appointments (Burriss, 2004; McGinnis, Allison, & Long 1981; Rudd et al., 2010; Su, 2011). High quality departments are likely to provide more resources and affiliation with a prestigious program may send a stronger signal of the scientist's ability, supporting future career goals (Dasgupta & David, 1994). Although these benefits might be countered by stress and pressure to perform, postdocs are believed to seek out the appointments that they believe will maximize their utility, constrained by their ability to signal their level of human capital (Zubieta, 2009). Presumably those postdocs who were able to obtain appointments in high-quality departments would also have been able to get appointments in lower-quality departments (Spence, 1973), so postdocs' presence in high quality departments is interpreted as a revealed preference for quality. For reasons of both reputation and resources, postdocs in high-quality departments are expected to be more satisfied.

Model

Dissatisfaction is modeled as a function of job characteristics, situational variables, demographics, and the organizational environment (Seashore & Taber, 1975). Job characteristics include finding the research interesting and the project's match to research interests. Situational variables include career goals, motivations, and the postdoc-advisor relationship. Demographic characteristics focus on those related to work-life balance. The organizational environment is considered in terms of the quality of the research doctoral program in which the postdoc is appointed.

These factors are incorporated into an ordered Probit model of postdoc dissatisfaction. The dependent variable is an ordinal variable representing the probability that a postdoc indicated dissatisfaction in response to the question "Overall, how satisfied are you with your current PostDoc experience?" The data section includes further detail on the construction of this variable.

The following equation represents the ordered Probit model:

$$\Pr(\text{dissatisfaction}) = y = \beta_0 + \beta_1[\text{research}] + \beta_2[\text{career goals}] + \beta_3[\text{postdoc-advisor interaction}] + \beta_5[\text{demographics}] + \beta_4[\text{program quality}] + e$$

To the extent that occupational and economic conditions, such as compensation and labor market opportunities, vary by scientific field, controls are included as field fixed effects.

Data

Analysis is based on the Science and Engineering PhD and PostDoc Survey (SEPPS) (Sauermaun & Roach, 2012, 2013).¹ Web surveys were sent to approximately 30,000 graduate students and postdocs whose names and email addresses were gathered from the websites of doctorate granting departments in the biological and health sciences, engineering, and physical and mathematical sciences at 39 large U.S. research universities.² Overall response rate for the survey was 30%. The substantive content of the survey is described in Sauermaun and Roach (2012) and a detailed discussion of the survey methodology is provided in Sauermaun and Roach (2013).

Our analysis is based on 1,137 respondents who submitted finished surveys and identified themselves as current postdocs in the biological sciences (510), health sciences (142), or physical and mathematical sciences (485).³ The biological sciences category includes biochemistry, biophysics, and structural biology; cell and developmental biology; ecology and evolutionary biology; genetics and genomics; and neuroscience/neurobiology. The health sciences category includes biology/integrated biology/integrated biomedical sciences; immunology and infectious disease; microbiology; and pharmacology, toxicology and environmental health. Physical and mathematical sciences includes astrophysics and astronomy, chemistry, computer science, and physics. In 373 observations with some item-level nonresponse, missing data were imputed using the method of iterated chained equations (StataCorp, 2013). The most frequently omitted data element (193 observations) was lab size, probably because the question asked for an exact number for labs with fewer than 25 members. Postdocs may have been unsure of the exact size of their lab. While the average reported lab sizes in the biological sciences were slightly smaller, differences in average lab size by field did not appear substantively meaningful, with 95% confidence intervals ranging from 10–13 in all cases.

Two types of evidence help establish the representativeness of the sample. First, survey respondents are compared to nonrespondents, based on differences between those who finished and submitted the survey and those who started the survey but did not complete the entire survey. There were 131 survey recipients who started the survey and identified themselves as postdocs, but did not finish and submit the survey. Of those unfinished surveys, 105 included responses to a question about satisfaction with the current postdoc appointment. There was no apparent relationship between reported satisfaction and whether the respondent finished the survey ($\chi^2 = 3.871$, $p = 0.794$). Respondents who started the survey and identified themselves as U.S. citizens were somewhat more likely to finish the survey ($\chi^2 = 12.667$, $p < 0.001$) than were those who did not report U.S. citizenship. Respondents in the physical and mathematical sciences, where more postdocs are from outside the United States, were also somewhat less likely to finish the survey compared to respondents in biological and health sciences ($\chi^2 = 6.356$, $p = 0.012$). Male and female respondents who started the survey appeared equally likely to finish it ($\chi^2 = 0.011$, $p = 0.918$). While data from surveys that were not finished and submitted are not included in the analysis, submitted surveys where individual questions were left blank are included. There appeared to be no correlation between satisfaction and the number of missing items for the variables used in the analysis ($r = 0.018$, $p = 0.541$). However, U.S. citizens did tend to have slightly fewer missing items ($r = -0.101$, $p < 0.001$). Postdocs' satisfaction with their appointments did not appear to influence their response rate, but language and cultural issues may have contributed to lower response rates from international postdocs.

Second, the sample is compared to archival data. The sample provides a reasonable representation of the postdoc population at major U.S. research universities based on demographic characteristics. The proportions of men and U.S. citizens were comparable to those found in other surveys, such as the 2009 NSF Survey of Graduate Students and Postdoctorates, which provides an institution-level census of postdocs. The current sample had slightly more male (58% vs. 56%) and slightly fewer U.S. citizen (47% vs. 49%) respondents in the biological and health sciences and approximately the same percentage of male (79%) and slightly fewer U.S. citizen (38% vs. 40%) respondents in the physical and mathematical sciences. The demographic makeup of the sample can also be compared to the population of those earning doctorates in the United States, as measured by the 2009 Survey of Earned Doctorates. Overall, 57% of these graduates are male and 70% are U.S. citizens. The current survey sample contains more men (66%) and more

TABLE 2
Descriptive Statistics

Variable	Mean	SE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 Dissatisfaction	-0.719	0.021	1															
2 Research interesting	0.945	0.008	-0.389	1														
3 Mismatch average	0.871	0.020	0.209	-0.183	1													
4 Shape current research	0.656	0.016	-0.227	0.175	-0.086	1												
5 Skills	0.861	0.011	-0.149	0.072	-0.115	0.018	1											
6 Faculty career plans	0.556	0.017	-0.167	0.140	-0.116	0.154	0.143	1										
7 Start year	2007.281	0.063	-0.049	-0.017	-0.032	-0.043	-0.069	-0.147	1									
8 Advisor ability	8.230	0.053	-0.194	0.093	-0.036	0.195	0.061	0.079	-0.019	1								
9 Advisor often	0.780	0.014	-0.122	0.041	-0.010	0.019	0.010	-0.012	0.004	-0.026	1							
10 Lab size	11.065	0.206	-0.055	0.027	-0.039	0.104	0.022	0.023	-0.047	0.302	-0.276	1						
11 High quality	0.303	0.016	-0.008	-0.008	-0.017	0.056	0.004	0.133	-0.019	0.097	-0.129	0.236	1					
12 Female	0.329	0.016	0.005	0.002	0.048	0.006	-0.011	-0.110	0.095	-0.037	-0.031	-0.042	-0.047	1				
13 Children	0.309	0.015	-0.030	0.011	0.031	-0.088	-0.024	-0.004	-0.153	0.023	-0.010	-0.013	-0.067	-0.061	1			
14 Married	0.691	0.015	-0.055	0.028	0.066	-0.020	-0.029	0.025	-0.058	0.018	-0.002	-0.005	0.028	0.004	0.407	1		
15 Biological sciences	0.469	0.017	-0.019	0.089	0.100	0.039	-0.008	0.020	-0.073	0.016	0.040	-0.118	-0.118	0.152	0.075	0.095	1	
16 Health sciences	0.117	0.011	0.069	-0.058	0.043	0.001	0.036	0.032	-0.051	-0.027	-0.051	-0.008	0.057	0.100	0.054	0.021	-0.340	1
17 Postdoc at PhD university	0.201	0.013	0.090	-0.059	0.043	0.001	-0.122	-0.092	0.193	-0.012	-0.017	-0.037	-0.033	0.003	0.002	0.023	0.064	0.021

noncitizens (50%), as would be expected because many postdocs come to the US after earning doctorates in other countries.

Descriptive statistics and a correlation matrix are provided in Table 2. No strong multicollinearity was evident among the independent variables. The strongest correlation between independent variables was between being married and having children ($r = 0.407, p < 0.001$).

Dependent Variable

Dissatisfaction. Postdocs were asked to respond to the question “Overall, how satisfied are you with your current PostDoc experience?” on a seven-point Likert scale ranging from “Very dissatisfied” to “Very satisfied.” The ordinal variable *dissatisfaction* was coded as 1 if the response was very dissatisfied, dissatisfied, or somewhat dissatisfied, 0 if the response was “Neither satisfied nor dissatisfied,” and -1 if the response indicated some degree of satisfaction.

Independent Variables

Research. Postdocs responded to the question “How interesting do you find your current research?” on a five-point Likert scale ranging from “Uninteresting” to “Interesting.” The variable *research interesting* was coded as 1 if the response was “Interesting” or “Moderately interesting” and 0 if the response was neutral or uninteresting.

The variable *mismatch average* measures the discrepancy between the postdoc’s current research and future research interests. The variable was created by averaging difference scores based on responses to six questions.

First, postdocs responded to the question “To what extent do you agree or disagree with the following phrases regarding the nature of your current research[?]” on five-point Likert scales ranging from “Strongly agree” to “Strongly disagree” with respect to three types of research: basic, applied, and development. Because the use of these terms varies in different contexts (Calvert, 2006), the following phrases were used to define the types of research: “My research contributes fundamental insights or theories (basic research),” “My research creates knowledge to solve practical problems (applied research),” and “My research uses knowledge to develop materials, devices, or software (development).”

Second, postdocs were asked to respond to the question “When thinking about the future, how interesting would you find the following kinds of work?” on five-point Likert scales ranging from “Uninteresting” to “Interesting.” They were presented with the same three types

of research defined previously. Difference scores were calculated as the absolute value of the difference between the current research project rating and the future research interest rating and the difference scores were averaged such that a higher score indicates a greater discrepancy between the postdoc's current research and future research interests.

Career Goals. Two career goals measures were included, one focused on long-term career plans and the second on the goal of skills development through the postdoc appointment.

Because postdoc appointments prepare students for research careers, a measure of the extent to which the respondent was likely to pursue a faculty career focused on research was used to account for alignment of the postdoc appointment with career goals. Subjects were asked to rank the following careers from most likely to pursue to least likely to pursue: "University faculty with an emphasis on research or development," "University faculty with an emphasis on teaching," "Government job with an emphasis on research or development," "Job in an established firm with an emphasis on research or development," "Job in a startup firm with an emphasis on research or development," and "Other career." To create a set of ordered rankings, the web survey was constructed so that a respondent could not give two careers equal rank. A binary variable *faculty career plans* was coded 1 if the respondent ranked a faculty research career as the most likely future career and coded 0 if any other career was ranked as most likely.

Postdocs were also asked "Thinking back to when you began your first PostDoc in [year], how important were the following factors in influencing your decision to do a PostDoc?" They were asked to rate four factors on a five-point Likert scale from "Extremely unimportant" to "Extremely important." The binary variable *skills* reflects response to the item "I wanted to deepen my skills in a particular research area." This item was rated important by the highest proportion of respondents. The *skills* variable was coded as 1 if the response was "Extremely important" or "Moderately important" and 0 if the response was neutral or unimportant.

Postdoc-Advisor Relationship. Four variables were used to measure this relationship. *Advisor ability* was measured as the response to "How would you rate the overall research accomplishments of your advisor relative to his/her peers in their field?" on a continuous scale from 0 to 10 anchored with the following descriptions: "Among Least Accomplished," "Below Average," "Average," "Above Average," and "Among Most Accomplished."

Advisor often was a binary variable based on the question "On aver-

age, how often do you directly interact with your advisor?" It was coded as 1 if the response indicated direct interaction at least once per week and 0 if interaction was less frequent.

Shape current research was a binary variable based on the question "How much freedom do you have in influencing the direction of your research project(s)?" It was coded 1 if the response indicated complete or great freedom and 0 if the response indicated some, little, or no freedom.

Lab size represented the response to the question "Including yourself, approximately how many members are in your primary research lab?" Responses ranged from 1 to 25 or more (8%).

Individual and Demographic. Four demographic variables were used. Binary variables measured *female* gender, whether the postdoc had any *children*, and whether the postdoc was *married*. *Start year* represented the year the respondent started the first postdoc appointment. Responses ranged from, 2002 to 2010, the year the study was conducted. Marriage and children were also interacted with female gender. The binary variable *postdoc at PhD university* recorded whether the postdoc appointment was at the same university where the postdoc completed the doctoral degree.

Dummy variables were also included for *biological sciences* and *health sciences*, with *physical and mathematical sciences* treated as the base category. In their analysis of job satisfaction in science faculty, Sabharwal and Corley (2009) found that correlates of satisfaction were similar for science and health professions faculty, while correlates were different for engineering and social science faculty. These field fixed-effects indicators were also interacted with gender.

Program Quality. Program quality was represented by a measure of the quality of the research doctoral program in which the postdoc was appointed. Program quality was operationalized with a binary variable coded as 1 for postdocs who were in appointments at top tier of programs based on the NRC Assessment of Research Doctoral Programs. This assessment reported a 90% confidence interval around each doctoral program's ranking based on various criteria (NRC, 2011). Z-scores were calculated based on each program's 5th percentile score for the regression-based ranking to allow comparison across fields. In some cases, rankings were imputed at the broad field or institution level if the survey response was not complete enough to identify a specific program. Approximately 25% of respondents were in the highest-ranked tier of programs with rankings 1.3 standard deviations better than the mean. Because the sample already focused on leading research universities, defining the top tier as broadly as the top 25% was appropriate to avoid leverage from large individual programs.

The model was estimated using ordered Probit regression analysis with postdocs' dissatisfaction as the dependent variable.⁴

Results

Table 3 summarizes the ordered Probit regression results. Model 1 is the main model. Model 2 adds a test for the effect of taking a postdoc appointment at the same university where one earned a doctorate. Results of the models are similar except for the additional test and some gender-specific effects. Reported coefficients are from Model 1 unless otherwise noted. Results for factors related to research, career goals, postdoc-advisor interaction, demographics, and program quality, are presented below.

Research

Engaging in interesting research showed the strongest inverse relationship with postdoc dissatisfaction ($b = -1.281, p < 0.001$). If there was a high degree of mismatch between a postdoc's current research and future research interests, the postdoc was more likely to be dissatisfied ($b = 0.263, p < 0.001$).

Career Goals

With respect to career interests, postdocs who intended to pursue faculty careers focused on research were less likely to be dissatisfied ($b = -0.402, p < 0.001$). Postdocs who considered skill development an important factor in taking their current appointment were also less likely to be dissatisfied ($b = -0.403$).

Postdoc-Advisor Relationship

Postdocs who interacted with their advisors at least once per week were less likely to be dissatisfied ($b = -0.475, p < 0.001$). The association between infrequent postdoc-advisor interaction and dissatisfaction could be interpreted as psychological contract breach if this level of interaction does not match the postdoc's expectation for the advising relationship (Lambert, Edwards, & Cable, 2003).

Postdocs who rated their advisors' research ability highly were less likely to be dissatisfied ($b = -0.117, p < 0.001$).

The effect of lab size was not statistically significant.

Demographic and Individual Factors

Married male postdocs were less likely to be dissatisfied ($b = -0.505, p = 0.009$). However, the interaction of marriage and female gender was associated with a higher probability of dissatisfaction ($b = 0.510, p =$

TABLE 3
 Ordered Probit Analysis of Postdoc Dissatisfaction

Variable	Model 1	Model 2
Research		
Research interesting	-1.281 *** (0.196)	-1.372 *** (0.170)
Mismatch average	0.263 *** (0.090)	0.411 *** (0.079)
Career plans		
Faculty career plans	-0.402 *** (0.121)	-0.283 * (.105)
Skills	-0.403 ** (0.147)	-0.368 * (0.124)
Postdoc-advisor interaction		
Advisor ability	-0.117 *** (0.035)	-0.125 *** (0.030)
Advisor often	-0.475 *** (0.136)	-0.536 *** (0.117)
Shape current research	-0.438 *** (0.116)	-0.508 *** (0.101)
Lab size	-0.013 (0.011)	-0.015 (0.010)
Individual and demographic		
Start year	-0.068 ** (0.030)	-0.090 ** (0.026)
Female	0.219 (0.265)	0.074 (0.227)
Children	0.187 (0.241)	0.087 (0.209)
Married	-0.505 ** (0.221)	-0.475 (0.194)
Female x Married	0.510 * (0.271)	0.435 (0.240)
Female x Children	-0.536 * (0.289)	-0.460 (0.253)
Female x Biological sciences	0.357 (0.275)	0.322 (0.239)
Female x Health sciences	-0.259 (0.365)	-0.636 + (0.313)

TABLE 3 (continued)
 Ordered Probit Analysis of Postdoc Dissatisfaction

Variable	Model 1	Model 2
Biological sciences	-0.153 (0.237)	-0.149 (0.203)
Health sciences	0.428 ⁺ (0.282)	0.660 * (0.243)
Postdoc at PhD university		0.312 * (0.133)
Program quality		
High quality	0.081 (0.135)	0.067 (0.124)
Constant 1	-138.499 ** (60.393)	-181.973 ** (51.604)
Constant 2	-138.103 ** (60.391)	-181.578 ** (51.603)
<i>n</i>	1,137	915

⁺ $p < 0.10$. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

0.033). Female postdocs with children, however, were less likely to be dissatisfied ($b = -0.536$, $p = 0.034$).

Model 2 indicated that taking a postdoc at one's doctoral institution was associated with a higher probability of dissatisfaction ($b = 0.312$, $p = 0.019$). Once this variable was added to the model, the gender-specific effects of marriage and children were no longer statistically significant. This relationship is consistent with taking a postdoc appointment at the doctoral university as a result of family-related work-life considerations.

There was a higher probability of dissatisfaction in the health sciences compared to physical and mathematical sciences ($b = 0.428$, $p = 0.078$). This effect was statistically significant after controlling for taking a postdoc at the doctoral institution ($b = 0.660$, $p = 0.019$) and concentrated among men, since the interaction effect of health sciences with female gender was negative ($b = -0.636$, $p = 0.082$).

Postdocs reported greater satisfaction the more recently they had begun their first postdoc appointment ($b = -0.068$, $p = 0.008$), confirming that dissatisfaction increases over time spent as a postdoc.

Program Quality

A surprising aspect of the preceding analysis was the absence of any significant beneficial effect from the quality of the academic department on postdoc satisfaction after controlling for the other variables in the model. Consistent with the findings of Scaffidi and Berman (2011) and Davis (2009), measures associated with advisors providing effective mentoring and oversight were associated with a lower probability of dissatisfaction. However, it is possible that faculty in high-quality doctoral research programs have so many competing priorities that they interact less frequently with their postdocs.

Seemingly unrelated regression was used to estimate a multiple mediation model (UCLA Academic Technology Services, n.d.) that illustrates how freedom to shape a project and less frequent advisor interaction may explain the relationship between quality and satisfaction (see Figure 1). High program quality was associated with less frequent advisor interaction ($b = -0.128, p < 0.001$) and greater freedom to shape the current research project ($b = 0.066, p = 0.065$). Further, both frequent advisor interaction ($b = -0.193, p < 0.001$) and freedom to shape the current research project ($b = -0.311, p < 0.001$) were negatively associated with dissatisfaction. The indirect effect of high program quality through advisor interaction was 0.025 ($p = 0.008$) and the effect through shaping the research project was -0.020 ($p = 0.053$). The total indirect effect was estimated to be -0.017 , which was not statistically significant ($p = 0.716$) as expected, because the indirect effects were of opposite sign and similar magnitude. Consistent with the paradox of autonomy (Trevelyan, 2001), postdocs in high quality programs appeared to appreciate the increased freedom to shape research projects, but this was offset by less access to advisors, resulting in no net gain from program quality. This finding is also consistent with the dependence of job satisfaction on both autonomy and feedback, especially for workers concerned about career growth (Loher et al., 1985).

While freedom to shape a project could theoretically result from minimal advisor interaction or cause the advisor to allocate less time to supervision, these data do not seem to show a relationship, causal or otherwise, between these variables. The correlation between freedom to shape a project and interacting with the advisor at least once per week was 0.019 ($p = 0.523$).

Chang, Hursting, Perkins, Dores, & Weed (2005) identify grant writing, publishing, teaching, and keeping up with the rapid pace of scientific advancement as demands that compete with postdocs for advisors' time in the interdisciplinary field they study, cancer prevention. Addi-

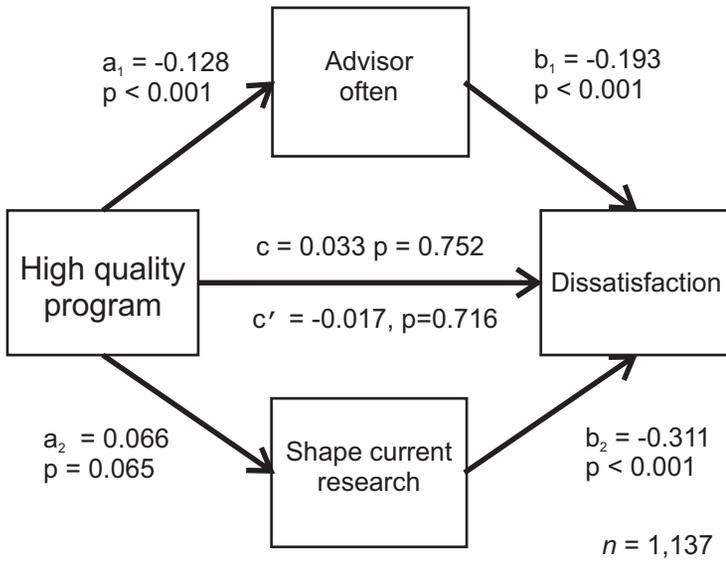


FIGURE 1. Relationship Between Program Quality and Postdoc Dissatisfaction. Frequency of advisor interaction and freedom to shape current research mediate relationship between program quality and postdoc dissatisfaction.

tional responsibilities may mediate the relationship between program quality and less frequent advisor interaction. An index of advisor activity was created based on postdocs' reports of their advisors' involvement in consulting, patenting, advisory board service, and founding or serving as an executive of an entrepreneurial venture. Based on 408 observations where postdocs reported advisor participation in commercialization activity, advisors in high-quality programs participated in a mean of 1.898 activities (CI = 1.516–2.279) and in low quality programs a mean of 0.956 activities (CI = 0.807–1.106).⁵

Modeling this relationship using seemingly unrelated regression (see Figure 2), reveals that high program quality is positively associated with the number of advisor activities ($b = 0.884$, $p < 0.001$). Similar results were obtained by estimating the relationship between program quality and number of activities using zero-inflated Poisson regression, an approach suitable for a dependent variable that is a count measure without overdispersion (StataCorp, 2009). There was also a significant negative association between the number of advisor activities and frequent advisor interaction with the postdoc ($b = -0.031$, $p = 0.016$). While there may be benefits to postdocs from working with advisors with broad ex-

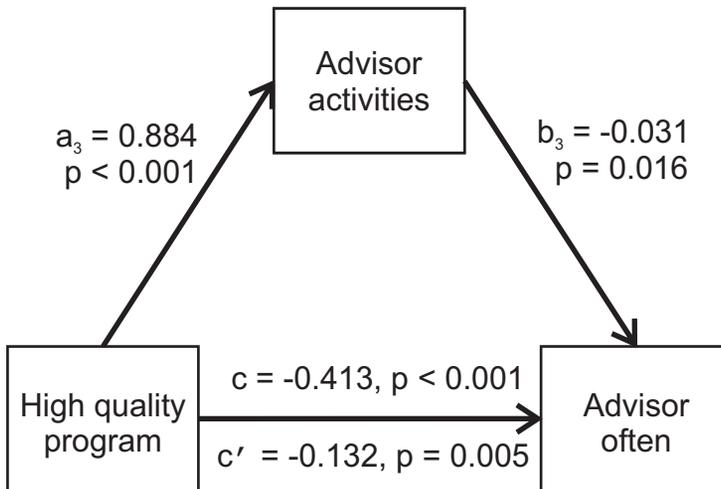


FIGURE 2. Program Quality and Advisor Interaction. Advisor activities mediate relationship between program quality and frequency of advisor interaction.

periences and an extensive network of contacts, there did appear to be less frequent interaction. Less frequent interaction was in turn associated with lower levels of satisfaction. Advisor activity measures partially mediated the relationship between program quality and frequency of advisor interaction with the postdoc ($c = -0.413, p < 0.001$; $c' = -0.132, p = 0.005$).

These findings appear consistent with those of Chang et al. (2005) in the sense that activities such as teaching and grant writing may also mediate the relationship between quality and advisor interaction. The findings provide an interesting complement to those of Bozeman and Gaughan (2011), who found that industry collaboration and research center affiliation did not appear to affect faculty job satisfaction. Such collaborations may influence the satisfaction of others. Bozeman and Gaughan also found a significant role for interaction with colleagues in determining job satisfaction. We find no effect for lab size, which might represent more general interaction with colleagues, but do find that regular interaction with the postdoc advisor reduces the probability of dissatisfaction.

There are a number of limitations associated with the measure of advisor activities. First, we have no measure available of the advisor's involvement in teaching and mentoring graduate students. It stands to

reason that this involvement would be high in high-quality doctoral programs. Second, only a binary measure of the advisor's involvement in an activity is available. It is unknown, for example, how much consulting activity the advisor did or on how many boards the advisor served. Third, the activities were reported by postdocs, not the advisors themselves. Nonresponse included those who left the question blank or indicated that they did not know if the advisor participated in a given activity. The high levels of nonresponse made imputation of missing data inappropriate for this variable. Advisors may not discuss commercialization activities with their postdocs. However, it seems likely that the postdocs who interacted more frequently with advisors would be more likely to be aware of their advisors' activities, which implies that this estimate of the effect of activities on interaction may be conservative. The measure could also be interpreted as a measure of postdocs' awareness of their advisor's commercialization activities.

One possible alternate explanation for the relationship between program quality and satisfaction would be that work-life issues on behalf of either the postdoc or advisor reduce the frequency of interaction. However, we find no evidence that postdocs in high quality programs would be more likely to face work-life balance conflicts based on age, gender, marital, or parental status (e.g., mean age in high quality programs = 31.840, CI = [31.456–32.226] compared to 32.307, CI = [32.0386–32.575]).

The postdoc's funding source may also influence the frequency of interaction with the advisor and freedom to shape the research project. There are two potential mechanisms for this influence, which unfortunately cannot be distinguished in these data. First, the postdoc may secure independent funding through a competitive portable fellowship, which would provide the postdoc a great deal of influence over the research project while potentially minimizing the need to interact with an advisor. The advisor may also be less invested in interacting with an independently funded postdoc than with one being paid from grant funding to contribute to the advisor's research. Alternatively, postdocs and advisors could collaborate in securing grant funding. In this case the postdoc and advisor are likely to interact more frequently, particularly during the grant writing process, and the postdoc may also have more input into the direction of the overall research project or the ability to shape one project within a larger program of research.

A final possibility is that reduced interaction with the advisor is a symptom rather than the cause of dissatisfaction. This cannot be dismissed, and the possibility of a negative feedback loop between dissatisfaction and advisor interaction should also be considered.

Discussion

Our analysis reveals several factors associated with a higher probability of postdoc dissatisfaction. The research being conducted and its relationship to the postdoc's interests and career goals, postdoc-advisor interaction, and demographic factors influence the postdoc experience. Dissatisfaction is less likely when the postdoc finds the current research project interesting, when the postdoc appointment is consistent with future career interests—especially as a faculty researcher—or was undertaken for skills development.

Our analysis suggests some interesting complexities in the relationship between dissatisfaction and some seemingly desirable qualities of postdoc appointments—working with a prominent advisor in a high quality research doctoral program. Working in a high-quality program does not appear to prevent dissatisfaction. If the advisor and postdoc do not interact at least once per week and the postdoc does not have freedom to shape the research projects, the potential benefits of a top program can become liabilities. The postdoc may avoid a potentially unsatisfactory experience by seeking out an appointment that allows greater autonomy and more frequent advisor interaction in a less prestigious department.

Because our findings come from those currently in postdoc appointments, they do not encompass all of the concerns of new PhDs. For example, PhDs who expected that they would be dissatisfied in a postdoc appointment were probably unlikely to pursue or accept a postdoc. Also, newly granted PhDs who were unable to secure a postdoc appointment are not included in our sample. Our results apply to new PhDs who were able to secure a postdoc appointment and optimistic enough about its benefits to accept one.

One factor that may influence satisfaction with postdoc appointments that we were unable to include in our model is compensation. However, respondents were asked to report what they believed the average salary for a postdoc appointment to be. While this question was answered by only 33% of respondents, the responses were quite consistent in the biological and health sciences and corresponded closely to the National Institutes of Health (2010) stipend standards which were set at \$37,740 for those with no experience and \$42,624 for those with two years' experience. The mean salary estimate provided by respondents in biological and health sciences was \$40,144 ($SD = 8.162$). Salary estimates were slightly higher and more varied in the physical and mathematical sciences (\$45,108, $SD = \$12,609$). Thus, we found little evidence of overly optimistic salary expectations. These responses seem to indicate

that postdocs either did not have clear expectations around salary, or that the expectations they had were accurate. Although the inability to include salary and benefits in our model is a limitation, Davis's 2009 analysis of the Sigma Xi survey supports our emphasis on nonmonetary factors.

These findings should be considered in terms of their implications for national policy, institutions, and individual scientists. One policy approach often advocated to improve the postdoc experience is to fund more postdocs through portable fellowships (Armbruster, 2008; COSEPUP, 2000). Portable fellowships have the advantage of increasing the postdoc's autonomy. However, they may be associated with less advisor interaction and less integration with labs and university communities. These findings about the influence of program quality on postdoc dissatisfaction suggest that there may be no net benefit if an increase in autonomy is accompanied by a decrease in advisor interaction.

Due to the cross-sectional nature of our study, macroeconomic and societal factors were by necessity held constant in our analysis. However, that does not mean that such factors are irrelevant. The historical perspective afforded by prior surveys of postdoc satisfaction (see Table 1) places the nature and role of postdoc appointments in a broader context. The experience of today's postdocs takes place in a context of uncertain funding and increasingly contingent employment, even for highly skilled workers (Stephan, 2012).

At the institutional level, universities and other research organizations may be able to avoid postdocs' dissatisfaction by providing structure to integrate postdocs into their work environments, even if the postdocs enjoy considerable autonomy in their research direction. Professional development offerings for faculty and postdocs can be designed to facilitate regular interaction as well as promoting the postdocs' empowerment and transition to independent research.

University offices of postdoctoral affairs and postdoc-run associations address some potential sources of dissatisfaction by offering training, orientation, networking, and integration into the local community (Felfly, 2011). Universities may have responded to earlier findings that nonmonetary aspects of the postdoc appointment increased postdoc satisfaction. Interventions such as the postdoc and advisor jointly developing a research plan at the outset, have been implemented by NSF (Davis, 2009).

While our findings may generalize more broadly to other postdocs, our sample is limited to those in the physical, biological, and health sciences located primarily at major research universities. Postdocs in engineering, the social sciences, and the humanities may have different

needs, as may postdocs in government agencies, independent research institutes, and industry settings.

Our survey analysis also has implications for new doctorate recipients who are considering a postdoc appointment. For those who have the opportunity to take a postdoc appointment that immerses them in interesting research and who plan to pursue faculty research careers, these findings indicate that postdocs are likely to find at least their first appointment satisfactory. However, recent data suggest that a faculty research career will be attainable for perhaps a quarter of those earning doctoral degrees in the sciences (Stephan, 2012, p. 170). Actively researching the job market and critically assessing one's own research abilities may bring some scientists to the conclusion to leave the academic job market sooner rather than later.

To address their dissatisfaction and lack of bargaining power, postdocs at some universities have organized through labor unions (Gerwin, 2010). Some universities have responded by creating offices of postdoc affairs. Postdocs have also engaged the political process, lobbying through the National Postdoc Association (NPA) and the American Association of Universities (AAU) (Scaffidi & Berman, 2011). Collective action by postdocs in both institutional and political contexts has focused on improving the quality of the postdoc experiences and decreasing dissatisfaction.

Future research on postdoc satisfaction would be advanced by the use of longitudinal studies that allow for the analysis of antecedents and consequences of satisfaction. For example, longitudinal data could be used to investigate the causal relationship between satisfaction and frequency of advisor interaction. It would also be beneficial to incorporate validated global and facet-based measures of satisfaction to facilitate connections to the existing body of satisfaction research in education and employment settings.

Notes

¹ The authors would like to express our gratitude to Henry Sauer mann and Michael Roach for access to the SEPPS data.

² The 20 universities with the most survey responses were Columbia University, Cornell, Duke University, Harvard, Johns Hopkins, Michigan State University, MIT, Ohio State University, UC Berkeley, UC Davis, UC Los Angeles, UC San Diego, UNC Chapel Hill, University of Chicago, University of Florida, University of Michigan, University of Washington, University of Wisconsin, Washington University St. Louis, and Yale.

³ Responses include postdocs identified in the original sampling frame who remained in their appointments, postdocs who had moved into another postdoc appointment, and

some doctoral students identified in the original sampling frame who had taken postdoctoral appointments.

⁴ Alternative specifications treating the dependent variable as multinomial with three unordered categories and as 5-point and 7-point Likert scales are available from the corresponding author. These alternative specifications did not appear to fit the data as well as the 3-category ordered Probit model.

⁵ These calculations include only those records where any advisor activities were reported. If records with no advisor activities reported are coded as zero rather than missing data, the mean number of activities in high quality programs is 0.584 activities (CI = 0.429–0.738) and in low quality programs is 0.360 activities (CI = 0.295–0.424).

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