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3

Improving the Postdoctoral Experience
An Empirical Approach

Geoff Davis

3.1 Introduction

The population of postdoctoral researchers ("postdocs") in the sciences and engineering has undergone a large expansion, nearly tripling over the last thirty years (National Science Foundation 1983–2003). While these scientists have produced tremendous quantities of new research, the relatively rapid growth in their ranks has been accompanied by two problems. First, the increase in the supply of postdocs has not been accompanied by a commensurate increase in the demand for them, at least in the academic sector. Second, large postdoctoral populations on campuses have strained institutions' capacities for providing these researchers with basic administrative oversight.

To address these concerns, leaders in the scientific community have called for changes in the postdoctoral experience, most notably improved compensation, augmented professional development opportunities, and increased administrative oversight. Each of these recommended measures comes at a cost, so assessing their relative benefits is important if institutions are to allocate their resources efficiently. In this chapter we will develop such an assessment.

The current absence of standards for the postdoctoral experience means that even within a single department there can be considerable variation in

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working conditions and compensation packages for postdocs. We can use this variability to gauge the impact of proposed changes to the postdoctoral experience. We use linear models to isolate the effects of specific measures on outcomes using data from a large-scale survey of postdocs. The results are striking: a handful of straightforward and relatively inexpensive measures appear to make a large difference in postdoc productivity and in the overall quality of the postdoctoral experience.

3.2 Background

A postdoctoral appointment is a short-term apprenticeship immediately following the completion of doctoral work that is designed to further prepare new Ph.D.s to become independent researchers. When postdoctoral positions were first instituted a century ago, they represented rare opportunities for some of the most promising young scholars to enhance their skills. In recent years, however, postdoctoral scholars have become increasingly common. As of 2003 there were 46,807 postdocs employed at academic institutions (NSF 1983–2003) and roughly 11,000 to 12,000 in other sectors (primarily government labs and industry) (National Academy of Sciences [NAS] 2000). Postdocs perform a substantial fraction of the skilled work in research labs and are responsible for a disproportionate share of new discoveries. A 1999 study found that 43 percent of first authors of research articles in *Science* were postdocs (Vogel 1999) (in science and engineering journals, the primary contributor to a paper is usually listed first).

The recent growth in the postdoctoral ranks is less a planned expansion than the result of a combination of economic and political factors. A substantial increase in the graduate student population in the late 1980s, fueled by increased National Science Foundation spending, a doubling of the budget of the National Institutes of Health over the latter half of the 1990s, and the increased ability of young researchers from the former Soviet Union, Eastern Europe, and China to come to the United States, have all increased the supply of postdocs. Over the same time period, university faculties—historically postdocs' primary employment destination—have grown much more slowly.

Many scientific and academic leaders have raised concerns about the side effects of this postdoc expansion. The first set of concerns has to do with structural changes in the labor market. In many fields, particularly in the life sciences, a postdoctoral appointment has evolved from an optional educational enhancement to a de facto prerequisite for a faculty position (Comission on Professionals in Science and Technology [CPST] 1998). The result has been a substantial lengthening of the time spent training: recent cohorts of Ph.D.s will not begin fully independent research until their

early forties (National Research Council [NRC] 2005). Tenure-track faculty positions have become more difficult to come by, and as a result many scholars spend increasing amounts of time in a frustrating postdoctoral "holding pattern" waiting for an academic job (NRC 1998). The diminishing probability of obtaining a faculty position has engendered fierce competition for relative advantage among researchers (Freeman et al. 2001a). Because universities are now able to draw upon a large pool of able would-be postdocs from less-developed countries, declining career opportunities have not resulted in a corresponding reduction in the supply of postdocs as in the past (Freeman 1990).

The second set of concerns is related to administrative matters: many institutions have been slow to address the needs of the postdoc population in a systematic fashion. "Postdoctoral education today is almost exactly where Ph.D. education was in the 1890s—very ad hoc," declares Steven B. Sample, president of the University of Southern California and chair of the Association of American Universities (AAU) Committee on Postdoctoral Education (NAS 2000). At some institutions postdocs are not classified either as students or as faculty/staff and, as a result, receive the benefits and protections of neither. Postdocs are in some cases poorly remunerated, retirement benefits are the exception rather than the rule, and nonmonetary aspects of work are in some cases only addressed on an improvised basis. There are no standard expectations for the supervision and mentorship of postdocs. Grievance resolution procedures are often ill-defined. Campus career services are usually geared exclusively toward undergraduates, occasionally graduate students, and only rarely postdocs.

Educational leaders, funding agencies, and postdocs all agree on the need for improvements in postdoctoral working conditions and have advocated five broad classes of practices be implemented by those employing and funding postdocs (Association of American Universities 1998; NRC 2005; National Postdoctoral Association 2005):

1. *Fellowships:* A larger fraction of postdocs should be funded individually (i.e., funded via a fellowship/traineeship as opposed to a grant made to a senior faculty member).
2. *Salary:* Postdoc stipends/salaries should be increased.
3. *Benefits:* Postdocs should receive basic benefits, particularly health and retirement benefits.
4. *Professional Development:* Employers of postdocs should provide professional development opportunities to prepare postdocs for a variety of careers.
5. *Structured Oversight:* Institutions employing postdocs should develop postdoc-specific policies and should require (or strongly encourage) such practices as individual development plans, regular reviews, and so on.

3.3 Improving Postdoctoral Training

Implementation of the practices recommended previously is underway on many campuses. More than forty institutions have created postdoctoral offices tasked with ensuring the well-being of their postdocs. Postdocs have started forming institution-level organizations to advocate for improvements in their working environments, often with support from their institution's administrations. At present there are roughly fifty such postdoctoral organizations in the United States, and the National Postdoctoral Association has been created with the goal of coordinating local efforts and sharing resources. Disciplinary societies have started postdoctoral initiatives to enhance the postdoctoral experience, one of the largest being the Postdoc Network at *Science*'s Next Wave, formed in November 2000. The National Science Foundation has sponsored two recent workshops intended to inform specific programmatic and policy initiatives that it might undertake (Merrimack Consultants, LLC 2003; Westat Inc. and Merrimack Consultants, LLC 2004). An important question for all stakeholders in postdoctoral training is determining which, if any, of the advocated measures have the greatest impact.

Because administrative responsibility for a postdoctoral appointment is typically held by a postdoc's advisor rather than by a department-level or university-level administrator, and because the implementation of recommended measures is just beginning, there is considerable variation in working conditions for postdocs even within individual departments. We can use this diversity of working environments to good effect: by comparing postdocs working with different recommended measures in place, we can estimate the effects of specific measures on the overall postdoctoral experience.

We analyze data from the Sigma Xi Postdoc Survey, a multi-campus survey of postdoctoral scholars carried out between December 2003 and April 2005. Sigma Xi conducted the survey at forty-seven institutions, including eighteen of the twenty largest academic employers of postdocs and the largest government employer. Over the course of the survey, Sigma Xi contacted some 22,400 postdocs, roughly 40 percent of the U.S. postdoc population. The survey's overall response rate was 38 percent (Sigma Xi 2005).

We tested the data set for nonresponse biases in two ways. First, we compared demographics of survey responders to known postdoc demographics at an institution that had detailed records of the sex, citizenship, and underrepresented minority status of its postdoctoral employees. The observed differences were within the range that would be expected due to sampling. Second, we looked for differences between early and late responders by regressing citizenship, sex, underrepresented minority status, and reported levels of overall satisfaction on the time between the start of the survey at a given institution and the time at which the respondent be-

gan the survey. Such differences, if present, suggest differences between responders and nonresponders. Our analysis suggested an underrepresentation of African American postdocs in the survey respondents as well as small underrepresentation of non-U.S.-citizen postdocs. No significant variation over time was found for other underrepresented minorities, for sex, or for levels of overall satisfaction. Further details of the nonresponse analysis may be found at http://postdoc.sigmaxi.org/results/tech_reports.

3.4 Outcome Measures

How do we measure the quality of postdoctoral experiences? One possibility is to follow the example of private foundations in evaluating the impact of their investments in young scientists. Recognizing that research careers span decades and that events during postdoctoral study can have an impact that unfolds over long periods of time, many foundations assess their impact by measuring publication rates and awards for those they fund some five to ten years afterwards (Pion and Ionescu-Pioggia 2003). These longitudinal studies have the advantage of allowing time for long-term investments to pay off, but they are expensive and labor-intensive. Bibliometric measures are useful in evaluating the success of postdocs who end up in tenure-track academic positions, but historically only about a third of postdocs have ended up in such positions (Regets 1998) and this fraction is likely shrinking (Davis 2005). We need a measure of success that is both easily obtainable and applicable to people with a broad range of career trajectories.

We construct four different measures of success metrics based on Sigma Xi survey data, two of which are subjective and two of which are objective:

1. *Subjective Success:* This measure reflects a postdoc's overall assessment of the current appointment. How satisfied is the postdoc with her current position? Is the current appointment doing a good job at preparing the postdoc to be an independent researcher? Is the appointment providing preparation for key aspects of the postdoc's future career?

Postdocs' opinions about the success of their appointments are one useful measure of success. Given that postdocs have typically completed more than ten years of undergraduate and graduate education, and a third have already done at least one previous postdoc, they should have some sense of what constitutes effective training. They also best know their own career goals and should have an idea of how well their current experiences are preparing them to meet those goals.

Ensuring that postdocs view their experiences as positive and successful can help institutions in hiring new postdocs, since satisfied postdocs are much more likely to recommend their current institution to others than dissatisfied postdocs (84 percent versus 30 percent). Information from post-

docs may influence undergraduates' career decisions as well (Freeman et al. 2001b), so preventing dissatisfaction in the postdoctoral ranks may be important in convincing younger students to pursue science careers.

2. *Advisor Relations:* This measure gauges the quality of the postdoc's relationship with his advisor. How would the postdoc rate his advisor's overall performance? How does the postdoc think his advisor would rate his overall performance? Does the postdoc consider his advisor to be a mentor?

In the idealized postdoctoral appointment, a postdoc's advisor serves as a mentor, and he and the postdoc have a close working relationship. Positive relationships are important because much of the training that takes place happens through the postdoc's interaction with his advisor.

3. *Absence of Conflict/Misconduct:* Has the postdoc had a conflict with her advisor? Has she seen misconduct in her work group? The absence of conflict and misconduct is a more objective complement to the subjective measure of advisor relations as described previously. The scores are related: postdocs who reported conflict/misconduct had an average advisor relations score that is 0.4 standard deviations lower than those who did not.

Keeping conflicts rare is particularly important because of the power disparity in the advisor/postdoc relationship: a serious conflict can end a postdoc's career. A recent survey (Martinson, Anderson, and de Vries 2005) shows relatively high rates of minor misconduct in science. In this context, a conflict and misconduct-free postdoc is one form of success.

4. *Productivity:* Postdoctoral appointments are training experiences, but they are also a source of new research. An appointment that is scientifically productive, as measured by papers and grant proposals submitted, can be considered successful.

To measure research productivity, we compute the rate at which postdocs submit papers to peer-reviewed journals per year. We also look at the rate of submission of papers for which the postdoc was the primary author as well as the rate of grant proposals submission. The Sigma Xi survey questions asked about the total number of papers and grants submitted as a postdoc, so our measures show productivity over a respondent's entire time as postdoc, not just for the current appointment.

The details and summary statistics for these success measures are shown in the appendix. Distributions of the measures are shown in figure 3.1. The subjective success and advisor relations have roughly normal distributions with a positive skew. The success distribution decays more slowly than a Gaussian, however, indicating the presence of more unsuccessful experiences than would be expected if the components of the measure were well-modeled as jointly Gaussian. Productivity, as measured by the number of papers submitted per year (excluding first-year postdocs to avoid small-

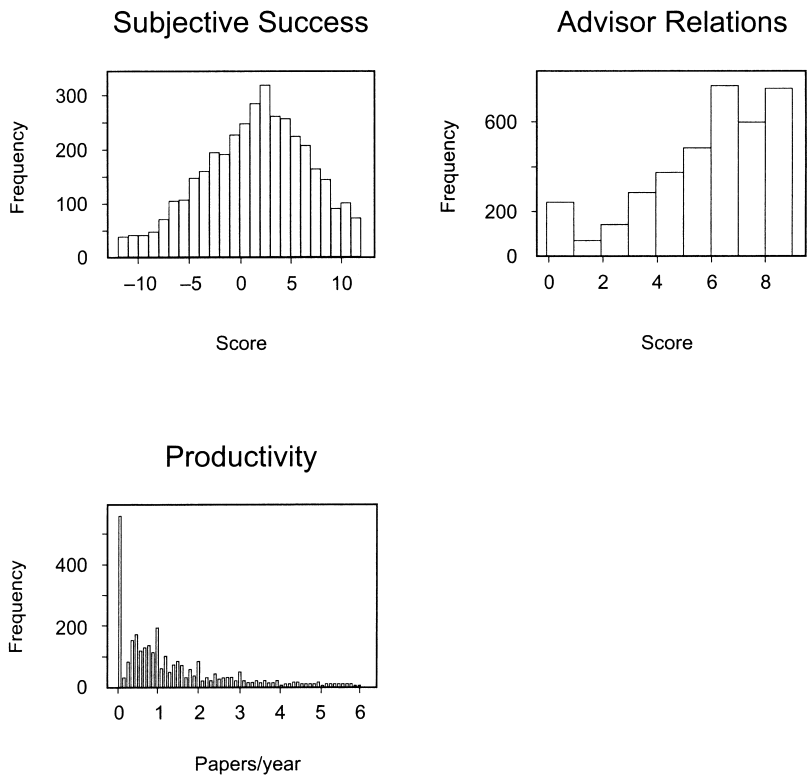

Fig. 3.1 Distributions of success measures

Table 3.1 Correlations between success measures

	Success	Advisor	No conflict	Productivity
Success	1.000	0.448	0.194	0.117
Advisor	0.448	1.000	0.142	0.094
No conflict	0.194	0.142	1.000	0.032
Productivity	0.117	0.094	0.032	1.000

denominator problems), is roughly exponentially distributed; the distribution of the log of the rate, excluding zeros, is roughly normal.

Pairwise correlations between the success measures are shown in table 3.1. There is a modest correlation between the subjective success and advisor relations measure, which is not surprising given the importance of the advisor-postdoc relationship in the overall success of the endeavor. Corre-

lations between other pairs of measures are all low, indicating that we are measuring disparate aspects of the experience.

3.5 Measures of Recommended Practices

We next define a set of measures of the implementation of the recommended practices. The first is straightforward: the *individual funding measure* is an indicator variable that set to 1 if the postdoc is funded individually. For the responses we use in our analysis (those from nonclinical-fellow postdocs working full-time), 20 percent report that their funding was from "a grant, contract, or fellowship that was awarded directly to [the postdoc]." The primary sources of these fellowships are private foundations/associations/disciplinary societies (37 percent) and NIH National Research Service Awards (22 percent).

The *salary measure* is simply the postdoc's annual salary. For the responses we analyze below, the mean salary was $39,305 and the standard deviation was $7,194. In our regressions we use the natural log of the salary, normalized to have zero mean and unit variance.

The other measures are normalized counts of features of the postdoctoral experience. The *structured oversight measure* counts the number of recommended practices such as research plans, formal reviews, and so on, that are implemented in the current appointment. The *professional development measure* counts the types of training postdocs reported receiving, either via formal coursework or on-the-job experience, in their current appointments. The *health insurance measure* is an indicator variable set to 1 if the postdoc has health insurance; the *benefits measure* counts the other types of benefits available in the current appointment. The summary statistics and individual items counted for each measure are detailed in the appendix. On average, postdocs indicated that six of the sixteen forms of structured oversight were implemented, they received professional development in six of the twelve areas counted, and reported that eleven of the eighteen forms of benefits were available; 98 percent received health insurance.

3.6 Distribution of Practices

Distributions of the measures of recommended practices are shown in figure 3.2. As with the outcome measures, most of the distributions resemble skewed normals, with heavy tails in some cases. Table 3.2 shows the pairwise correlations between the measures. There is a weak correlation between the structured oversight and professional development measures that likely arises from some institutions devoting more resources to postdocs via both oversight and formal training offerings. The other pairwise correlations are all very low.

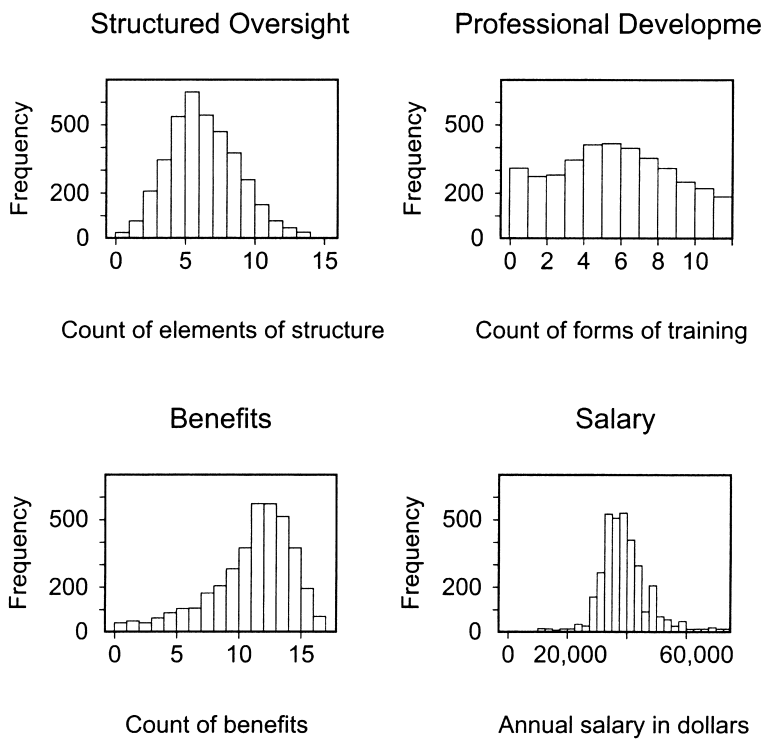

Fig. 3.2 Distributions of recommended practices measures

Table 3.2 Correlations between measures of recommended practices

	Structured oversight	Professional development	Benefits	log(Salary)	Funding
Structured Oversight	1.000	0.302	0.130	0.022	−0.074
Professional Development	0.302	1.000	0.106	0.024	0.045
Benefits	0.130	0.106	1.000	0.016	−0.099
log(Salary)	0.022	0.024	0.016	1.000	0.114
Funding	−0.074	0.045	−0.099	0.114	1.000

Table 3.3 shows regressions of the recommended practices measures on institution, field, duration variables, and postdoc demographics. There are citizenship-related differences in pay and likelihood of independent funding (citizens and permanent residents earn 4.7 percent more than temporary visa holders, about $1,850/year, and have 82 percent higher odds of being independently funded), and postdocs with medical degrees report

Table 3.3 **Recommended practices measures regressed on demographic variables**

	Structure	Prof dev.	Health	Benefits	Log(Salary)	Funding
(Intercept)	0.379**	−0.369*	13.532	**0.387*****	**−0.532*****	−2.723
	(0.136)	(0.149)	(271.983)	(0.113)	(0.095)	(7.192)
Male	0.111**	0.04	−0.381*	0.03	0.015	−0.062
	(0.034)	(0.037)	(0.180)	(0.028)	(0.024)	(0.057)
Citizen_or_pr	−0.065.	0.299***	0.282	0.021	**0.260*****	**0.604*****
	(0.035)	(0.038)	(0.180)	(0.029)	(0.024)	(0.059)
Underrepresented	−0.037	−0.044	−0.327	−0.004	0.089	0.280.
	(0.093)	(0.102)	(0.495)	(0.077)	(0.065)	(0.145)
Married	0.017	0.072.	−0.142	−0.046	−0.032	−0.057
	(0.038)	(0.042)	(0.206)	(0.032)	(0.027)	(0.065)
Children	0.076.	−0.029	−0.248	−0.060.	**0.078****	0.046
	(0.041)	(0.044)	(0.207)	(0.034)	(0.028)	(0.069)
Age	0.054**	−0.029	−0.049	−0.048**	0.028*	**−0.166*****
	(0.019)	(0.021)	(0.092)	(0.016)	(0.014)	(0.035)
Medical_degree	0.103.	**0.180****	−0.884**	−0.005	0.076.	0.108
	(0.057)	(0.062)	(0.276)	(0.047)	(0.040)	(0.098)
Years_total	−0.026	−0.056**	0.271*	0.046**	**0.145*****	−0.05
	(0.018)	(0.020)	(0.121)	(0.015)	(0.013)	(0.037)
Years_current	**−0.099*****	**0.077*****	−0.206	−0.061***	0.024	**0.220*****
	(0.021)	(0.023)	(0.136)	(0.018)	(0.015)	(0.041)
Previous_postdocs	0.045	0.011	−0.118	−0.067*	−0.02	−0.184**
	(0.034)	(0.037)	(0.180)	(0.028)	(0.024)	(0.067)
N	3,552	3,552	3,477	3,552	3,552	3,463

Notes: Standard errors are shown in parentheses. Robust regression with an M-estimator was used for the structure, professional development, benefits, and salary measures. Logistic regression was used for health insurance and independent funding. All regressions also included 46 dummy variables for institution and 95 for field of research; these have been omitted to conserve space. For this and subsequent regressions, ***designates a p-value of < 0.001, **designates a p-value of < 0.01, *designates a p-value of < 0.05, and . designates a p-value of < 0.10. Boldface indicates that coefficients maintain their sign and statistical significance (p-value < 0.10 for the smaller data sets) in regressions on subsets of the data consisting of (1) all postdocs in their first appointment and (2) all postdocs in their second appointment.

greater levels of professional development. Apart from these, there are few other demographically linked differences in the best practices measures. Related analyses of variance for the continuously valued practices measures support our claim of heterogeneity in working conditions within institutions. Field and institution together explain just 11 percent of the variation in structured oversight, 5 percent of the variation in professional development, 19 percent of the variation in benefits, and 28 percent of the variation in log(salary).

Many of the structured oversight questions ask about events that occurred at the start of a postdoc's current appointment, so the negative "years_current" coefficient in the structured oversight model may result from postdocs forgetting details of the start of their appointment over time.

The positive "years_current" coefficient for professional development is consistent with the notion that training accumulates over the course of one's appointment. The positive "years_current" term in funding probably results from postdocs extending existing appointments upon the receipt of a fellowship.

One thing we must be careful of in these regressions is that we are combining responses from postdocs in their first appointments with those from postdocs who have had multiple appointments. This creates potential endogeneity problems, since several of our model variables are likely to be linked to the reasons postdocs choose to pursue or not pursue further appointments. For example, those with high subjective success in a first appointment may be more likely to pursue a second, while those experiencing conflicts in a first appointment may be less likely to do so. We can reduce this problem by performing separate regressions for those in their first appointment, those in their second and so on, so that we have more uniform pools of responses. However, such a disaggregation comes at the price of smaller data sets to work with and reduced test power.

In table 3.3 we introduce a convention that we will use for the remainder of our regressions: we will report results for the full data set, and then, as a confirmatory measure, we will perform separate regressions for postdocs in their first appointment and those in their second. We show in boldface coefficients that maintain their sign and statistical significance in the pooled data as well as the two disaggregated sets (a p-value ≤ 0.10 on the smaller data sets) and will focus our discussion on those coefficients.

3.7 Impact of Recommended Practices

Do recommended practices for the postdoctoral experience have any measurable benefits? Table 3.4 provides a rough answer: each pair of columns compares components of our outcome measures for postdocs reporting the highest and lowest levels of our measures of recommended practices.

Postdocs reporting the highest levels of oversight and professional development are more satisfied, give their advisors higher ratings, report fewer conflicts with their advisors, and are more productive than those reporting the lowest levels. High levels of benefits are associated with similar but smaller differences in three of the four categories. Those with individual funding show little difference from those without. Health insurance is accompanied by higher rates of satisfaction and better advisor grades, but lower productivity (likely because an absence of health insurance is most commonly the result of a selective fellowship with inadequate provisions for benefits). Salary appears to be associated with only minimal differences in the measures.

Table 3.4 **Components of success measures as a function of funding mechanism, levels of structured oversight, professional development, benefits, and salary**

	Direct funding		Structured oversight		Professional development	
	Yes	No	Top 25%	Bottom 25%	Top 25%	Bottom 25%
Satisfied	74%	69%	78%	63%	82%	56%
Advisor grade	3.0	3.1	3.4	2.8	3.4	2.7
Conflict	14%	14%	11%	18%	11%	17%
Papers/year	1.1	1.2	1.3	1.0	1.3	1.1
	Health insurance		Benefits		Salary	
	Yes	No	Top 25%	Bottom 25%	Top 25% ≥ $42,000	Bottom 25% < $35,000
Satisfied	71%	61%	75%	65%	71%	67%
Advisor grade	3.1	2.9	3.1	3.0	3.0	3.1
Conflict	14%	14%	12%	15%	16%	13%
Papers/year	1.1	1.5	1.2	1.2	1.2	1.2

Notes: Each pair of columns compares those with and without direct funding/health insurance and those in the top quartile and bottom quartile of structured oversight, professional development, and so forth. "Satisfied" is the percent reporting that they are satisfied overall with their position. "Advisor grade" is the average "grade" (on a 4 point scale) that postdocs give their advisors. "Conflict" is the percent reporting that they have experienced a conflict with their advisor. "Publications/year" is the average number of peer-reviewed publications submitted per year for those who have been postdocs for at least twelve months.

While table 3.4 is a useful start, we need to be much more careful if we are to obtain a reliable estimate of impact. There are important differences in the postdoctoral experience across research fields and institutions, and there is interplay between the contributing factors. Special populations may have different experiences. To test the hypothesis that the recommended practices impact our success measures while controlling for these various potentially confounding factors, we perform a set of multivariate regressions.

We regress each of the measures of success on log salary, dummy variables for independent funding and health insurance, and our composite measures of structured oversight, professional development, and benefits. We add variables to control for sex, underrepresented minority status, citizenship, age, marital status, children, field of research (ninety-six fields), and employing institution (forty-seven institutions). For those reporting research in multiple fields, we weight the field dummy variables so that they sum to 1. We control for years spent in the current postdoctoral appointment, years spent in all postdoctoral appointments taken together, and the total number of postdoctoral appointments. To compensate for

differing response rates at surveyed institutions, we give each sample a weight inversely proportional to the response rate at the institution. We use a robust regression (an M-estimator with a Huber influence function) for the subjective success and advisor relations, logistic regression for the binary-valued absence of conflict measure, and Poisson regression with log(total_years) as an offset for the rates of production of papers and grants.

The results, shown in table 3.5, confirm what we observed in our initial comparison: professional development is positively associated with all of our success measures, and structured oversight with five or six measures. The structured oversight relationship is the most robust in that the effects are seen in the full data set as well as in the subsets, consisting of those in their first appointment and those in their second. Professional development may have a smaller impact after a postdoc's first appointment, since skills learned in a previous appointment do not need to be relearned, or its effects may be too small to see in the smaller set of postdocs in their second appointment (860 of the 3,552 postdocs). Professional development is the strongest predictor of subjective success and of good advisor relations, and structured oversight the strongest predictor of an absence of conflicts.

Those with independent funding submitted grant proposals at a 66 percent greater rate than those without (not surprising, since one must request funding in order to receive it), and reported greater levels of subjective success, but there appear to be few other measurable benefits. Salaries are weakly linked with subjective success and positive advisor relations, but the association is not significant for those in their second appointments.

Both salary and structured oversight are positively correlated with the rate of paper production, both for all peer-reviewed papers as well as for first-authored papers. One standard deviation in each (for salary, a 19 percent difference, or roughly $7,600) corresponds to 6.5 to 7 percent increase in the rate of paper production. The simplest explanation for the salary relationship is that the most productive postdocs are better able to land higher-paying appointments. For the structured oversight/productivity relationship, in contrast, there is reason to believe that there is causality in the opposite direction.

3.8 Correlates of Success

To better understand the reasons for the observed associations, we perform another set of regressions, this time replacing the composite measures of structured oversight and professional development with their individual components. The results are shown in table 3.6. As before, we will take the conservative approach of focusing on relationships that appear in not only the full data set, but also in separate regressions for those in first and second appointments.

Table 3.5 **Success measures regressed on recommended practices measures and other descriptive variables**

	Subjective success	Advisor relations	Absence of conflict	Papers submitted	1st authored papers	Grants submitted
(Intercept)	0.696***	0.162	3.621	0.651***	0.111	−0.341
	(0.161)	(0.156)	(11.031)	(0.076)	(0.101)	(2.170)
Structure	**0.157*****	**0.159*****	**0.239*****	**0.065*****	**0.063*****	−0.021.
	(0.016)	(0.015)	(0.037)	(0.007)	(0.010)	(0.011)
Professional_ development	**0.453*****	**0.242*****	0.151***	0.058***	0.062***	**0.127*****
	(0.015)	(0.015)	(0.034)	(0.007)	(0.009)	(0.011)
Health	−0.240*	0.084	−0.632*	−0.193***	−0.102	0.112
	(0.109)	(0.106)	(0.255)	(0.049)	(0.067)	(0.074)
Benefits	**0.102*****	−0.006	0.152***	0.018*	−0.000	0.046***
	(0.017)	(0.016)	(0.035)	(0.008)	(0.010)	(0.012)
Log(salary)	0.049**	0.069***	0.053	**0.070*****	**0.069*****	−0.033*
	(0.018)	(0.018)	(0.041)	(0.008)	(0.011)	(0.013)
Funding	**0.158*****	0.031	0.160*	0.006	0.037	**0.506*****
	(0.037)	(0.036)	(0.081)	(0.017)	(0.023)	(0.022)
Sex	0.090**	0.014	0.147*	**0.137*****	**0.147*****	−0.084***
	(0.030)	(0.029)	(0.066)	(0.014)	(0.020)	(0.021)
Citizen_or_pr	0.073*	0.030	0.097	**−0.111*****	**−0.129*****	**0.276*****
	(0.031)	(0.030)	(0.069)	(0.014)	(0.020)	(0.022)
Underrepresented	0.041	0.036	−0.065	−0.048	−0.110.	0.033
	(0.082)	(0.079)	(0.188)	(0.040)	(0.057)	(0.052)
Married	−0.026	0.054.	−0.012	0.044**	**0.058****	−0.099***
	(0.034)	(0.033)	(0.075)	(0.016)	(0.022)	(0.023)
Children	−0.018	0.034	0.184*	0.014	0.105***	0.018
	(0.036)	(0.035)	(0.078)	(0.016)	(0.022)	(0.024)
Age	−0.031.	**−0.059*****	−0.084*	**0.038*****	−0.000	−0.051***
	(0.017)	(0.017)	(0.037)	(0.008)	(0.011)	(0.012)
Medical_degree	−0.155**	−0.093.	**−0.466*****	−0.040.	0.022	−0.237***
	(0.050)	(0.049)	(0.101)	(0.024)	(0.033)	(0.040)
Total_years	−0.003	−0.040*	−0.034	**−0.058*****	**−0.090*****	**−0.143*****
	(0.016)	(0.016)	(0.032)	(0.005)	(0.008)	(0.011)
Current_years	**−0.043***	0.025	**−0.324*****	**−0.043*****	**−0.047*****	−0.101***
	(0.019)	(0.018)	(0.037)	(0.006)	(0.009)	(0.013)
Previous_postdocs	−0.067*	0.012	−0.134*	0.087***	0.121***	−0.106***
	(0.030)	(0.029)	(0.057)	(0.011)	(0.014)	(0.023)
N	3,552	3,552	3,552	3,348	3,348	3,348

Notes: Standard errors are shown in parentheses. Robust regression with an M-estimator was used for the subjective success and advisor relations measures. Logistic regression was used for the absence of conflict measure. Poisson regression with a log(total_years) offset was used for the measures of productivity. All regressions also included 46 dummy variables for institution and 95 for field of research; these have been omitted to conserve space.

***Designates a p-value of < 0.001.

**Designates a p-value of < 0.01.

*Designates a p-value of < 0.05.

.Designates a p-value of < 0.10.

Table 3.6 **Success measures regressed on individual components of structured oversight and professional development**

	Subjective success	Advisor relations	Absence of conflict	Papers submitted	First author	Grants submitted
(Intercept)	**−0.557*****	−0.709***	2.898	0.427***	−0.100	−0.822
	(0.165)	(0.166)	(10.899)	(0.082)	(0.110)	(2.146)
Plan_oral	0.066.	0.142***	−0.023	−0.024	−0.037	−0.052*
	(0.036)	(0.036)	(0.080)	(0.017)	(0.024)	(0.025)
Plan_written	0.099.	0.191***	0.116	**0.204*****	**0.260*****	**0.226*****
	(0.056)	(0.056)	(0.138)	(0.026)	(0.035)	(0.039)
Advisor_plan	**0.254*****	**0.242*****	0.421***	−0.038*	−0.067**	−0.025
	(0.038)	(0.038)	(0.095)	(0.019)	(0.026)	(0.028)
Evaluations	0.113**	0.129**	−0.124	0.086***	0.131***	0.039
	(0.040)	(0.040)	(0.095)	(0.019)	(0.026)	(0.030)
Contract_ compensation	−0.024	−0.019	−0.177*	−0.033*	−0.000	0.114***
	(0.035)	(0.035)	(0.081)	(0.017)	(0.023)	(0.026)
Contract_benefits	0.019	−0.014	**0.262****	0.124***	0.154***	−0.073**
	(0.034)	(0.034)	(0.083)	(0.016)	(0.022)	(0.025)
Contract_ responsibilities	−0.069.	−0.007	−0.184*	−0.083***	−0.048*	0.076**
	(0.038)	(0.038)	(0.090)	(0.018)	(0.024)	(0.028)
Contract_advisor	0.062	0.075	0.088	0.040	0.009	−0.034
	(0.051)	(0.051)	(0.132)	(0.024)	(0.033)	(0.038)
Contract_term	0.035	0.072.	0.001	0.001	−0.089***	0.024
	(0.038)	(0.038)	(0.089)	(0.019)	(0.026)	(0.028)
Policy_authorship	0.062	0.038	**−0.429*****	0.071**	0.151***	−0.094*
	(0.048)	(0.048)	(0.117)	(0.022)	(0.031)	(0.037)
Policy_misconduct	0.099*	0.057	0.169	**0.129*****	**0.156*****	−0.036
	(0.046)	(0.046)	(0.108)	(0.022)	(0.030)	(0.032)
Policy_grievance	0.053	0.060	0.257*	−0.045.	**−0.119*****	**−0.091****
	(0.048)	(0.048)	(0.121)	(0.023)	(0.032)	(0.034)
Policy_ip	0.016	0.037	**0.572*****	−0.010	−0.079**	0.053.
	(0.045)	(0.045)	(0.112)	(0.022)	(0.030)	(0.032)
Placement_services	0.083	0.034	−0.234.	0.143***	0.067.	0.006
	(0.054)	(0.054)	(0.123)	(0.025)	(0.034)	(0.039)
Career_counseling	0.226***	0.081	0.347**	−0.081**	−0.071.	0.021
	(0.055)	(0.055)	(0.120)	(0.026)	(0.036)	(0.040)
Ethics	**0.129*****	0.100**	0.231**	−0.018	−0.025	−0.007
	(0.034)	(0.034)	(0.077)	(0.016)	(0.022)	(0.024)
Writing	0.102**	0.174***	−0.115	0.079***	0.098***	−0.093**
	(0.039)	(0.039)	(0.089)	(0.019)	(0.027)	(0.030)
Public_speaking	0.094*	0.064	0.037	−0.105***	−0.103***	−0.001
	(0.039)	(0.039)	(0.089)	(0.019)	(0.027)	(0.031)
Teaching	**0.475*****	0.096**	0.197*	**0.108*****	0.128***	−0.097***
	(0.033)	(0.033)	(0.080)	(0.016)	(0.022)	(0.023)
Proposal_writing	**0.166*****	**0.120*****	**0.221****	−0.031*	−0.035	**0.867*****
	(0.033)	(0.033)	(0.076)	(0.016)	(0.022)	(0.030)
Lab_management	0.231***	0.183***	−0.274***	0.046**	−0.052*	0.035
	(0.035)	(0.035)	(0.083)	(0.017)	(0.024)	(0.026)
Project_management	**0.128*****	0.080*	**0.324*****	−0.072***	−0.091***	0.030
	(0.035)	(0.035)	(0.082)	(0.017)	(0.024)	(0.026)

(*continued*)

Table 3.6 (continued)

	Subjective success	Advisor relations	Absence of conflict	Papers submitted	First author	Grants submitted
Negotiating	0.073*	−0.019	**−0.359*** **	**0.172*** **	**0.209*** **	0.118***
	(0.037)	(0.037)	(0.089)	(0.018)	(0.024)	(0.026)
Ip	0.053	−0.001	−0.015	−0.006	0.026	−0.021
	(0.035)	(0.035)	(0.083)	(0.017)	(0.023)	(0.025)
Conflict_resolution	0.058	0.014	0.225**	0.002	0.064**	−0.042
	(0.036)	(0.036)	(0.087)	(0.017)	(0.024)	(0.026)
English	−0.081*	−0.050	−0.192*	0.023	0.019	**−0.097*** **
	(0.032)	(0.032)	(0.076)	(0.015)	(0.021)	(0.024)
Non_academic	**0.228*** **	**0.106*** **	**0.388*** **	−0.000	−0.013	−0.022
	(0.030)	(0.030)	(0.071)	(0.014)	(0.020)	(0.021)
Health	−0.216*	0.072	−0.621*	−0.167***	−0.054	0.091
	(0.105)	(0.105)	(0.263)	(0.049)	(0.068)	(0.074)
Benefits	**0.081*** **	−0.008	0.135***	0.020*	0.006	0.051***
	(0.016)	(0.016)	(0.036)	(0.008)	(0.011)	(0.012)
Log(salary)	0.043*	0.071***	0.056	**0.070*** **	**0.074*** **	−0.045***
	(0.018)	(0.018)	(0.042)	(0.008)	(0.011)	(0.013)
Funding	**0.118*** **	0.003	0.100	−0.008	0.020	**0.431*** **
	(0.035)	(0.035)	(0.083)	(0.017)	(0.024)	(0.023)
Male	0.093**	0.019	0.168*	**0.139*** **	**0.146*** **	−0.092***
	(0.029)	(0.029)	(0.067)	(0.014)	(0.020)	(0.021)
Citizen_or_pr	−0.004	−0.013	−0.002	−0.078***	−0.085***	**0.191*** **
	(0.033)	(0.033)	(0.076)	(0.016)	(0.022)	(0.024)
Underrepresented	0.069	0.044	−0.029	−0.113**	**−0.217*** **	0.061
	(0.079)	(0.079)	(0.192)	(0.041)	(0.058)	(0.053)
Married	−0.022	0.053	0.017	0.037*	**0.048***	−0.085***
	(0.032)	(0.032)	(0.077)	(0.016)	(0.022)	(0.023)
Children	0.005	0.040	0.205*	0.004	0.088***	0.036
	(0.034)	(0.034)	(0.080)	(0.016)	(0.022)	(0.025)
Age	−0.034*	**−0.057*** **	−0.092*	**0.032*** **	−0.008	−0.047***
	(0.016)	(0.016)	(0.038)	(0.008)	(0.011)	(0.013)
Medical_degree	**−0.164*** **	−0.090.	**−0.494*** **	−0.044.	0.012	−0.210***
	(0.048)	(0.048)	(0.104)	(0.024)	(0.034)	(0.040)
Total_years	0.003	−0.038*	−0.056.	**−0.055*** **	**−0.085*** **	**−0.143*** **
	(0.016)	(0.016)	(0.033)	(0.005)	(0.008)	(0.012)
Current_years	**−0.043***	0.025	**−0.292*** **	**−0.044*** **	−0.047***	−0.100***
	(0.018)	(0.018)	(0.038)	(0.007)	(0.009)	(0.013)
Previous_postdocs	−0.086**	0.008	−0.105.	0.082***	0.118***	−0.095***
	(0.028)	(0.028)	(0.059)	(0.011)	(0.014)	(0.024)
N	3,552	3,552	3,552	3,348	3,348	3,348

Notes: Standard errors are shown in parentheses. Robust regression with an M-estimator was used for the subjective success and advisor relations measures. Logistic regression was used for the absence of conflict measure. Poisson regression with a log(total_years) offset was used for the measures of productivity. All regressions also included 46 dummy variables for institution and 95 for field of research; these have been omitted to conserve space.

***Designates a p-value of < 0.001.

**Designates a p-value of < 0.01.

*Designates a p-value of < 0.05.

.Designates a p-value of < 0.10.

3.8.1 Research/Career Plans

The most interesting observation is that postdocs who plan their experience with their advisors at the outset of their appointments fare substantially better than those who do not. Postdocs with a written plan submit papers to peer-reviewed journals at a 23 percent higher rate, first-authored papers at a 30 percent higher rate, and grant proposals at a 25 percent higher rate than those without a written plan. These findings are in keeping with Drucker's assertion that knowledge workers' productivity requires that they have a role in shaping their responsibilities (Drucker 1999). Postdocs with plans that discuss what their advisors will do as well as what they will do score 0.25 standard deviations higher on the subjective success measure and 0.24 standard deviations higher on the advisor relations measure than those with no plan or a plan that includes no advisor component.

Correlation does not necessarily mean causation, of course, but there are a number of mechanisms by which the process of planning might give rise to the positive outcomes we observe. A trivial explanation is that those with the greatest propensity to write are more likely to write both plans and papers. It is unlikely that this is the only mechanism, however.

Contracts play a key role in labor exchanges. Without a contract guaranteeing compensation or credit for investments such as training or extra hours in the lab, postdocs may forego these investments even when they would benefit all parties involved (the hold-up problem) (Jacobsen and Skillman 2004). By serving as contracts, plans can foster greater levels of investment, leading to greater productivity.

Satisfaction in some cases is a function more of how one's circumstances compare to one's expectations than of one's absolute circumstances (Kahneman, Diener, and Schwarz 1999). Plans may improve satisfaction levels and relations with advisors by serving as an effective expectation-setting mechanism. Indeed, while 20 percent of postdocs who made no plan reported that their advisor was not meeting their initial expectations, only 5 percent of postdocs with written plans that addressed their advisors' obligations as well as their own reported similar disappointment.

Plans can help postdocs clarify their career goals early on. Postdocs with plans then have more time to pursue training opportunities appropriate for their goals. As a result they may judge their appointments as providing better preparation than those with no plans.

When postdocs and their advisors craft a plan together, they are making an explicit commitment to each other. Studies have shown that even when promises are nonbinding, people who make them in writing are more likely to follow through (Cialdini 1993). Thus, well-crafted plans can promote success by helping to ensure that both advisors and postdocs live up to their obligations.

Planning is widely used as an important tool for managing time and resources efficiently, and they may increase postdocs' productivity by focusing their efforts. Additionally, a number of studies have found positive associations between job satisfaction and worker performance, particularly among professional and managerial workers (Iaffaldano and Muchinsky 1985; Petty, McGee, and Cavender 1984), so plans' expectation setting function may have additional productivity benefits.

3.8.2 Professional Development

Exposure to nonacademic careers and training in teaching skills, proposal writing, project management, and ethics are all associated with greater levels of subjective success. Exposure to nonacademic careers and training in proposal writing are further correlated with better advisor relations and lower rates of conflict. These associations make sense, since training in these skills helps postdocs perform their jobs more effectively and prepares them for their future careers.

On-the-job training has been linked to increased rates of worker productivity in other sectors (Bartel 1994), and postdoc productivity appears to benefit from some forms of training. Those reporting training in proposal writing reported submitting grant proposals at a 138 percent higher rate than those reporting no training. The direction of causality probably goes both ways here: formal training in proposal writing likely helps postdocs with the grant writing process, but also those who write grants may consider the act itself a form of experiential training. Training in negotiation skills is associated with a 19 percent increase in the rate of paper submissions. Negotiation skills may help postdocs to obtain resources needed for their research, as 50 percent of those reporting negotiation skills training are completely satisfied with the funds available for research and travel, compared with 39 percent of those without such training.

3.8.3 Salary and Benefits

Compensation levels have been linked to workplace satisfaction among doctorate holders (Bender and Heywood 2004; Moguerou 2002), and our findings are consistent. Benefits, another form of compensation, have a similar relationship to satisfaction. Both of these factors have a much smaller effect than intrinsic features of employment such as levels of structure and training, however a finding that is in keeping with past studies (Iaffaldano and Muchinsky 1985). The weak relationship between compensation and satisfaction fits in with the notion of the academic labor market as a tournament (Lazear and Rosen 1981; Freeman 2001b) in which incentives for postdocs are provided by the prospect of future, more lucrative employment as tenured faculty members, rather than current salaries.

3.8.4 Contracts and Policies

Ambiguity in the ownership of intellectual property is a potential source of contention. Clear policies can help prevent problems from arising, and indeed, we see that such policies are associated with 77 percent lower odds of conflict between postdoc and advisor.

Contracts/letters of appointment that spell out a postdoc's benefits are also associated with lower rates of conflict. This association may arise because such contracts are proxies for well-organized central administration of postdocs.

Under the tournament interpretation of the academic labor market, the prospect of future employment motivates postdocs more than current compensation levels, and credit for work done is important for gaining access to those future opportunities. Enforcement of authorship rights should increase paper writing by increasing the likelihood that effort will be rewarded. Authorship policies are in fact associated with an increase in publications, but also, interestingly, a decrease in grant writing (both only for postdocs in their first appointments). One interpretation is that at institutions where authorship rights are less secure, postdocs shift their efforts into activities for which credit is more assured, such as applying for fellowships.

Somewhat surprisingly, postdocs who report a local authorship policy report 54 percent higher odds of conflict. One recent survey suggests that authorship problems are fairly common (Tarnow, Cohen, and de Young 2007), but authorship policies, in contrast, are relatively rare—only 23 percent of postdocs report knowing about such a policy. In this light, two explanations present themselves. One possibility is that authorship policies may simply encourage greater rates of reporting of a common but underreported problem. Alternatively, the individuals most likely to be aware of authorship policies are those who have experienced problems, or, similarly, the institutions most likely to have authorship policies in place may be the ones with the highest rates of authorship problems.

3.8.5 Time

All of the productivity metrics worsen over time. For every year spent in a postdoctoral appointment, postdocs submit papers at a 6 percent lower rate. This decline is offset in part by an age-linked productivity increase of 0.7 percent per year—perhaps maturity brings with it better judgment about research directions to pursue or better time management skills.

For each previous appointment a postdoc has held, there is an 8 percent increase in overall paper production and a 13 percent increase in the rate of first authored papers. This finding is particularly striking given that changing appointments can be a disruptive process involving relocating and even changing fields.

One explanation is that the selection process for subsequent appointments is linked to productivity. The least productive people are less able to obtain subsequent appointments, and some fraction of the most productive people find better opportunities. The positive "previous_postdocs" term suggests that on the balance, low productivity is the more likely reason for leaving the postdoc pool, and hence multiple appointments are a sign of fitness with respect to the selection function.

3.8.6 Demographics

Men have higher levels of subjective success than women, at least in the first appointment, which agrees with previous findings (Moguerou 2002). Studies have found that male scientists publish at a higher rate than female scientists, and our findings are consistent. Xie and Shauman (2003) report that these sex-linked productivity differences for more senior scientists disappear when the type of institution and available resources are taken into account. However, the sex-linked productivity differences we observe for postdocs persist after controlling for institution, family structure, and levels of supervision and training. Interestingly, women submit grant proposals at a higher rate, which suggests that some of the difference in publication rates may be the result of different resource allocation strategies.

Citizens of the United States submit more grant proposals but fewer papers than those on temporary visas, again suggesting different allocations of time and other resources. Underrepresented minority postdocs submit first authored papers at a lower rate than majority postdocs.

Those with medical degrees report lower levels of subjective success and have 64 percent greater odds of reporting a conflict with their advisors than postdocs with other types of degrees. The reasons may have to do with differing cultures and workplace environments in medical fields.

3.9 Causality

Structured oversight and professional development are correlated with our success measures, but we have not proved a causal relationship. The links we observe could arise from several possible mechanisms:

1. Structured oversight and professional development may directly cause greater levels of success via the previously discussed mechanisms.
2. Structured oversight and professional development might be associated with a common unobserved underlying cause. For example, these practices might be indicators of a particularly well-managed lab, or of a principal investigator with ample resources.
3. Positions that offer professional development and oversight might attract intrinsically successful postdocs.

4. Successful postdocs might be more likely to seek out professional development opportunities and to initiate such things as research plans.

In the first two scenarios, some aspect or aspects of the current appointment cause success; in the second two, success is linked to the individual postdoc and is not affected by local circumstances. It may well be that more than one or even all of these mechanisms play some role; the interesting question is whether any predominate.

One way to establish causation would be to conduct an experiment: a major funder of postdocs such as the National Institutes of Health could test the effects of practices in a manner similar to a clinical trial for a new drug. Funded postdocs could be randomly assigned to one of two variants of a funding program, one with a requirement, say, of a written plan, and one without.

Absent such an experiment, we must rely on more indirect means. One approach is to test whether there is a relationship between an exogenous indicator of success and the amount of structure and professional development present in appointments. A positive relationship would suggest that intrinsically successful people seek out or create structure and professional development as in scenarios 3 and 4 in the previous list. Conversely, the absence of a relationship would suggest that structure and professional development play a causal role or are indicators of some other causal factor as in scenarios 1 and 2.

One crude indicator of a postdoc's ability is the quality of her doctorate-granting program. We obtained a National Research Council (NRC) quality rating (NRC 1995) for the doctorate-granting department of 38 percent of the surveyed postdocs (some did not earn their doctorate in the United States, some earned their degrees in departments that were not rated, and some did not provide their Ph.D.-granting department). Table 3.7 shows a regression of each of our measures of recommended practices on demographic characteristics, field, and the normalized NRC rating for the postdoc's doctorate-granting department. We do not control for institution, as doing so would hide a tendency for those from more prestigious Ph.D. programs gravitating to institutions with greater overall structure or training.

We see in table 3.7 that NRC rating does have some effect: each standard deviation increase in the rating (0.86 points on a 5 point scale) is associated with 71 percent greater odds of independent funding and a 1.4 percent higher salary. There is no indication, however, that those from higher rated doctorate-granting programs either seek out or create more structure or professional development opportunities for themselves. A regression like the one in table 3.4 minus the institutional controls shows that the "fitter" postdocs with multiple appointments do not do so either. These findings cast doubt on scenarios 3 and 4 in the list and suggest that structured over-

Table 3.7 **Regression of recommended practices measures on demographic variables, field, and the National Research Council rating for the postdoc's doctorate-granting department**

	Structure	Prof dev.	Health	Benefits	log(Salary)	Funding
(Intercept)	0.216	−0.152	11.172.	**0.540****	−0.420*	**−2.593*****
	(0.212)	(0.230)	(6.478)	(0.206)	(0.164)	(0.362)
Male	0.061	0.036	−0.293	0.087	0.041	0
	(0.055)	(0.059)	(0.289)	(0.053)	(0.042)	(0.089)
Citizen_or_pr	−0.087	0.163*	−1.935**	0.02	**0.225*****	**0.885*****
	(0.065)	(0.070)	(0.716)	(0.063)	(0.050)	(0.120)
Underrepresented	−0.13	−0.098	−0.943.	−0.131	0.032	**0.441***
	(0.129)	(0.139)	(0.511)	(0.125)	(0.100)	(0.196)
Married	−0.025	0.096	−0.352	−0.059	−0.001	0.102
	(0.060)	(0.065)	(0.378)	(0.058)	(0.046)	(0.100)
Children	0.082	−0.085	−0.547.	−0.061	0.092.	0.041
	(0.064)	(0.070)	(0.326)	(0.063)	(0.050)	(0.104)
Age	0.070*	−0.031	0.068	−0.068*	−0.001	−0.057
	(0.033)	(0.036)	(0.199)	(0.032)	(0.026)	(0.058)
Medical_degree	0.063	−0.222	14.794	−0.023	0.111	0.391
	(0.191)	(0.207)	(848.151)	(0.185)	(0.148)	(0.297)
Nrc	−0.054*	0.042	0.188	−0.035	**0.082*****	**0.537*****
	(0.026)	(0.028)	(0.137)	(0.025)	(0.020)	(0.049)
Total_years	−0.027	−0.088*	−0.168	0.014	**0.116*****	0.015
	(0.041)	(0.045)	(0.264)	(0.040)	(0.032)	(0.073)
Current_years	−0.094*	0.119*	0.086	−0.015	0.101**	0.202**
	(0.045)	(0.048)	(0.271)	(0.043)	(0.035)	(0.077)
Previous_postdocs	−0.09	0.011	0.944	−0.079	0.193**	−0.336*
	(0.079)	(0.086)	(0.614)	(0.077)	(0.061)	(0.143)
N	1,375	1,375	1,364	1,375	1,375	1,343

Notes: Standard errors are shown in parentheses. A robust regression with an M-estimator was used for the structure, professional development, benefits, and salary measures. Logistic regression was used for health insurance and funding. The regression also included 95 dummy variables for field of research; these have been omitted to conserve space.

***Designates a p-value of < 0.001.

**Designates a p-value of < 0.01.

*Designates a p-value of < 0.05.

.Designates a p-value of < 0.10.

sight and professional development either cause the observed benefits themselves or are markers for some other underlying cause.

3.10 Conclusion

Of the five major classes of practices that have been recommended for postdoctoral appointments, structured oversight and professional development appear to have the greatest impact. In particular, written research

plans that lay out the obligations of both postdoc and advisor are correlated with broad-ranging and substantial benefits. Exposure to nonacademic careers and training in teaching skills, proposal writing, and project management are also associated with multiple positive outcomes. There are plausible causal mechanisms that can explain these correlations and indirect evidence against noncausal alternative explanations.

Because structured oversight measures are sufficiently simple and commonsensical, many are advocating their implementation without waiting for irrefutable evidence of their efficacy. Recent reports from the National Science Foundation (Merrimack Consultants, LLC 2003) and the National Academies (NRC 2005) require written plans detailing advisor and postdoc contributions as part of the grant application process. Given the potential benefits of plans together with their relative rarity at present (11 percent of postdocs reported having a written plan; 34 percent had a plan that detailed their advisor's obligations as well as their own), such a requirement has the potential to improve the postdoctoral experience considerably. If a universal requirement for written research/career plans were to bring about the same productivity increase that we see with existing, voluntary plans (an outcome that is by no means assured), the resulting increase in paper production would be the equivalent of having more than 10,000 additional postdocs working in the United States. Regardless, there is much to be gained from a more systematic investigation of the process of scientific training and research.

Appendix

The following describes components of the measures of success, measures of recommended practices measures, and other descriptive variables. Component abbreviations are shown in italic. Summary statistics are in parentheses. The statistics are for responses from nonclinical-fellow postdocs working full-time. Missing values were imputed with mean values where appropriate. To improve readability, standard deviations are not shown for binary-valued data.

Subjective Success Measure

The measure is the normalized sum of the following items, scored as described below (before normalization $\mu = 2.02$, $\sigma = 5.19$, $N = 3{,}719$):

- *sat_overall* ($\mu = 0.71$, $\sigma = 1.24$, $N = 3{,}669$) = overall satisfaction with current position; –2 points for very dissatisfied, –1 point for somewhat dissatisfied, 0 for neither satisfied nor dissatisfied, 1 point for somewhat satisfied, 2 points for very satisfied.

- Extent to which respondent is being prepared for his/her future career in the following areas: *prep_research* ($\mu = 1.14$, $\sigma = 1.08$, N = 3,701) = research skills, *prep_teaching* ($\mu = -0.87$, $\sigma = 1.33$, N = 3,667) = teaching skills, *prep_management* ($\mu = -0.27$, $\sigma = 1.39$, N = 3,669) = management skills, *prep_communications* ($\mu = 0.39$, $\sigma = 1.31$, N = 3,688) = communications skills; 2 points for "excellent," 1 point for "good," 0 points for "fair," –1 points for "poor."
- *independent* ($\mu = 0.92$, $\sigma = 0.98$, N = 3,675) = 2 points for "strongly agree" that position is preparing respondent to be an independent researcher, 1 point for "agree," 0 points for "neither agree nor disagree,"–1 point for "disagree,"–2 points for "strongly disagree."

Advisor Relations Measure

The measure is the normalized sum of the following items, scored as described below ($\mu = 6.33$, $\sigma = 2.37$, N = 3,719 before normalization):

- *postdoc_grade* ($\mu = 3.29$, $\sigma = 0.72$, N = 3,228) = estimated letter grade advisor would give respondent for overall performance (A = 4 points, . . . F = 0 points).
- *advisor_grade* ($\mu = 3.06$, $\sigma = 0.96$, N = 3,463) = grade respondent would give advisor for overall performance (A = 4 points, . . . F = 0 points).
- *mentor* ($\mu = 0.73$, N = 3,190) = Does postdoc consider advisor to be a mentor? (1 point for "yes," 0 points for "no").

Absence of Conflict Measure

($\mu = 0.86$, N = 3,719) = 0 if the respondent has experienced one of the following with/from his/her advisor: a dispute over authorship or author precedence, a dispute over intellectual property ownership, a dispute over research ethics, discrimination or harassment, or other research misconduct; 1 if not.

Productivity Measures

- *papers* ($\mu = 2.89$, $\sigma = 4.11$, N = 3,478) = the number of papers submitted to peer-reviewed journals while a postdoc. Includes papers submitted during all postdoctoral appointments, not just the current one.
- *first_authored* ($\mu = 1.55$, $\sigma = 2.48$, N = 3,478) = the number of papers for which the postdoc is the primary author submitted to peer-reviewed journals while a postdoc.
- *grants* ($\mu = 1.25$, $\sigma = 1.94$, N = 3,478) = the number of grant proposals submitted while a postdoc.

Structured Oversight Measure

The measure is the normalized sum of the following items, scored as described below ($\mu = 6.34$, $\sigma = 2.43$, N = 3,719 before normalization):

- *plan_oral* ($\mu = 0.62$, N = 3,632) = Did the respondent and postdoc advisor set expectations orally at the beginning of the appointment for what postdoc would do and learn?
- *plan_written* ($\mu = 0.10$, N = 3,632) = Did the respondent and postdoc advisor set expectations in writing at the beginning of the appointment for what postdoc would do and learn?
- *advisor_plan* ($\mu = 0.35$, N = 3,082) = (For those who made a plan/plans) Did the plan set expectations for what advisor would contribute to the experience?
- *evaluations* ($\mu = 0.22$, N = 3,086) = Does advisor provide formal performance evaluations?
- (For those with a letter of appointment or contract) 1 point for each of the following pieces of information included in the contract: *contract_compensation* ($\mu = 0.65$, N = 3,123) = Compensation, *contract_benefits* ($\mu = 0.43$, N = 3,123) = Benefits, *contract_responsibilities* ($\mu = 0.37$, N = 3,123) = Your responsibilities, *contract_advisor* ($\mu = 0.14$, N = 3,123) = Advisor's responsibilities, *contract_term* ($\mu = 0.77$, N = 3,123) = Term of appointment.
- 1 point for each of the following policies at institution: *policy_authorship* ($\mu = 0.233$, N = 2,500) = determining paper authorship and author precedence, *policy_misconduct* ($\mu = 0.47$, N = 2,545) = defining misconduct, *policy_grievance* ($\mu = 0.34$, N = 2,314) = resolving grievances, *policy_ip* ($\mu = 0.40$, N = 2,375) = determining ownership of intellectual property.
- *placement_services* ($\mu = 0.56$, N = 1,422) = Are job placement services available at institution?
- *career_counseling* ($\mu = 0.68$, N = 1,638) = Is career counseling available at organization?

Professional Development Measure

The measure is the normalized sum of the following items, scored as described below ($\mu = 6.10$, $\sigma = 3.19$, N = 3,719 before normalization):

- Source of respondent's primary training in current position. 1 point for each of the following answered "workshop/seminar/formal coursework," 0 points for "informal, on-the-job training,"–1 points for "no training": *ethics* ($\mu = 0.68$, N = 3,669) = Research ethics, *writing* ($\mu = 0.71$, N = 3,678) = Writing skills, *public_speaking* ($\mu = 0.72$, N = 3,675) = Public speaking skills, *teaching* ($\mu = 0.34$, N = 3,656) = Teaching skills, *proposal_writing* ($\mu = 0.64$, N = 3,671) = Grant or

proposal writing, *lab_management* ($\mu = 0.51$, N = 3,658) = Group or lab management, *project_management* ($\mu = 0.57$, N = 3,649) = Project management, *negotiating* ($\mu = 0.32$, N = 3,644) = Negotiating skills, *ip* ($\mu = 0.35$, N = 3,636) = Intellectual property, *conflict_resolution* ($\mu = 0.38$, N = 3,644) = Conflict resolution skills, *english* ($\mu = 0.42$, N = 3,629) = English language skills.

- *non_academic* ($\mu = 0.48$, N = 3,609) = How much has current position exposed respondents to opportunities outside of academia? One point for "A lot" or "Some," 0 for "Not at all."

Health Insurance Measure

- (*health*) ($\mu = 0.98$, N = 3,635) = 1 if health insurance is available at the postdoc's institution, 0 if not.

Benefits Measure

The measure is the normalized sum of the following items, scored as described below ($\mu = 11.2$, $\sigma = 3.2$, N = 3,719 before normalization):

- A measure of benefits available to the respondent at his/her institution. Scoring: 1 point for each of the following: *health_family* ($\mu = 0.91$, N = 3,235) = Health insurance for your family, *dental* ($\mu = 0.80$, N = 3,484) = Dental insurance, *vision* ($\mu = 0.59$, N = 2,744) = Vision insurance, *disability* ($\mu = 0.71$, N = 2,032) = Disability insurance, *life* ($\mu = 0.73$, N = 2,603) = Life insurance, *mental_health* ($\mu = 0.82$, N = 2,108) = Counseling/mental health services, *retirement* ($\mu = 0.50$, N = 2,840) = Retirement plan, *child_care* ($\mu = 0.46$, N = 1,949) = Child care, *family_leave* ($\mu = 0.71$, N = 1,765) = Family leave, *gym* ($\mu = 0.78$, N = 3,118) = Athletic facilities, *parking* ($\mu = 0.79$, N = 3,296) = Parking, *tuition* ($\mu = 0.67$, N = 2,024) = Tuition/fees for courses at institution, *flex_spending* ($\mu = 0.57$, N = 1,941) = Flexible spending account/medical savings account, *credit_union* ($\mu = 0.80$, N = 2,454) = Credit union, *401k* ($\mu = 0.53$, N = 2,065) = Voluntary, tax-deferred savings plan, *housing* ($\mu = 0.22$, N = 2,268) = Subsidized housing, *transportation* ($\mu = 0.62$, N = 2,644) = Public transportation subsidies.

Independent Funding Measure

- *funding* ($\mu = 0.21$, N = 3,620) = 1 if the postdoc receives independent funding (e.g., a fellowship), 0 if not.

Salary Measure

- *log_salary* ($\mu = 10.6$, $\sigma = 0.18$, N = 3,225 before normalization) = The postdoc's annual salary normalized to zero mean, unit variance.

Other Descriptive Variables

- *male* ($\mu = 0.57$, N = 3,684) = 1 if the postdoc is male, 0 if not.
- *citizen_or_pr* ($\mu = 0.46$, N = 3,683) = 1 if the postdoc is a citizen or a permanent resident of the United States, 0 if not.
- *underrepresented* ($\mu = 0.03$, N = 3,622) = 1 if the postdoc is a citizen or permanent resident who is a member of an underrepresented minority group, 0 if not.
- *married* ($\mu = 0.69$, N = 3,638) = 1 if the postdoc is married or partnered, 0 if not.
- *children* ($\mu = 0.34$, N = 3,636) = 1 if the postdoc has children, 0 if not.
- *age* ($\mu = 33.4$, $\sigma = 4.41$, N = 3,571 before normalization) = The postdoc's age. Normalized to mean 0, variance 1 in regressions.
- *total_years* ($\mu = 2.42$, $\sigma = 1.82$, N = 3,589) = The total number of years spent as a postdoc in all postdoctoral positions taken together.
- *current_years* ($\mu = 1.82$, $\sigma = 1.34$, N = 3,621) = The total number of years spent in the current postdoctoral position.
- *previous_postdocs* ($\mu = 0.41$, $\sigma = 0.73$, N = 3,704) = The number of previous postdoctoral appointments the postdoc has held.
- *medical_degree* ($\mu = 0.12$, N = 3,719) = 1 if the postdoc has a medical degree (an MD, DDS, or DVM), 0 if not.
- *institution* (Not shown) = A set of 46 dummy variables (coded with deviation coding) for the postdoc's institution.
- *field* (Not shown) = A set of 95 dummy variables used for the postdoc's field(s) of research. If a postdoc specifies more than one field, the field variables are normalized so that they sum to 1.
- *nrc* ($\mu = 3.56$, $\sigma = 0.86$, N = 1,405 before normalization) = The National Research Council's quality rating for the postdoc's doctorate-granting department.

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