Why We Are Here: A Review of the Literature on Motivations for Postdoctoral Appointments

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Abstract:
This paper reviews the academic literature, government and professional association reports, and publicly available data to summarize what we know about who becomes a postdoc. As scientists become more likely to participate and persist in postdoctoral appointments, scientists and those who employ, fund, organize, and support them would like to better understand who becomes a postdoc and why. Although many of the most talented new PhDs become postdocs, there is concern that their talents are not fully utilized in these appointments. One way to approach the question of who becomes a postdoc is by examining individual characteristics like personal motivation, human capital, and demographics. Another approach considers the role of characteristics of the doctoral institution. This review considers both approaches to integrate our knowledge of individual and institutional determinants of postdoctoral study.

Introduction:

As postdoctoral appointments have become more common and prolonged (Stephan and Ma, 2005*)* especially in the life sciences, scientists and those who employ them seek to better understand who becomes a postdoctoral scholar (postdoc) and why. There is concern that postdoctoral appointments have become a holding pattern and a source of cheap labor (Mishagina, 2009, Puljak and Sharif, 2009). On the other hand, other studies have found that the most talented new PhDs also become postdocs (Zumeta, 1985, Vogel, 1999). This paper reviews the literature and advances a series of propositions to guide future research on new entrants to the postdoctoral workforce.

This review summarizes the academic literature regarding which new doctorates in the life sciences, physical sciences, and engineering take postdoctoral appointments. The emphasis of the review is on U.S. postdoctoral appointments. However, studies taking place in other countries are also included in the review when relevant.

A great deal of descriptive information has been compiled about postdocs. Table 1 provides a chronology of key surveys and descriptive work on postdocs. Table 2 describes ongoing NSF surveys that include data about postdocs.

The appendix provides a summary of the empirical studies that are the focus of this review, including methodology, key findings, and limitations. Note that many of the studies are cross-sectional or retrospective, based on secondary or archival data, reflect samples from earlier time periods, and/or are largely descriptive in nature. Several study postdocs outside the U.S.

This review is organized in three sections. The first section reviews evidence about how individual-level factors such as motivation, ability, and demographics predict who becomes a postdoc. The second section discusses how university-level factors such as prestige of the university and features of the doctoral program predict who becomes a postdoc. The third section describes potential interactions between individual-level and university-level influences.

Individual-level

Prior research suggests that there are a number of individual-level factors that influence whether someone will become a postdoc. These factors, suggested by psychological, economic, and sociological theory, can be categorized as motivational, human capital, and demographic. The existing literature on these factors in postdoctoral appointments is reviewed in the following section and motivates a series of propositions.

Table 1
Large-scale surveys about postdoctoral scholars in the United States

Survey Name	Description
Postdoctoral Work in American Universities	16 campus visits conducted in 1960 by Bernard Berelson and David Sills f006Fr the Association of American Universities. Surveys were also mailed to presidents of AAU member schools and the researchers met with representatives of major funders of postdoctoral research.
The invisible university: Postdoctoral education in the United States	Conducted by Richard Curtis for the National Research Council. A census of postdocs was taken in spring 1967 and qualitative data were gathered from interviews in agencies, non-profits, and industry and 20 campus visits.
Postdoctoral appointments and disappointments	A two stage study directed by Porter Coggeshall for the National Research Council. In the first stage, survey responses from 150 university administrators and 40 R&D managers in government and industry as well as information from site visits to 50 departments at 15 universities were used to craft a proposal for the study's second stage, which included surveys of chairmen of science and engineering departments, U.S. citizens with science and engineering doctorates, and foreign citizens holding postdoctoral appointments.
Extending the educational ladder: The changing quality and value of postdoctoral study	Compiled by William Zumeta for the National Science Foundation, Spencer Foundation, Lilly Endowment, Mellon Foundation, and Higher Education Research Institute. Data are from a variety of sources including the Survey of Earned Doctorates, Survey of Doctorate Recipients, other National Research Council Surveys, and the Higher Education Research Institute Survey of Mobility and Nontraditional Careers in Science and Engineering.
PhDs 10 years later	Conducted by Maresi Nerad and Joseph Cerny in approximately 1996 and funded by the Mellon Foundation and National Science Foundation. The survey involved almost 6000 PhDs from biochemistry, computer science, electrical ,engineering, English, mathematics, and political science from 61 institutions.
Enhancing the postdoctoral experience for scientists and engineers	Directed by Deborah Stine for the Committee on Science, Engineering, and Public Policy from 1999-2000. Includes analysis of secondary data as well as survey responses from 40 organizations with postdoctoral appointees, 39 focus groups, and a day-long workshop with over 100 participants.
Sigma Xi	Led by Geoff Davis for Sigma Xi in partnership with the National Postdoctoral Association, Science NextWave Postdoc Network between December 2003 and April 2005. Includes 22,400 postdocs at 47 institutions.
American Association of Universities	Conducted by the Graduate and Postdoctoral Education Committee of the AAU in March 2005. Included responses from 25 public and 14 private AAU universities.

Table 2
Ongoing National Science Foundation longitudinal surveys with data about postdoctoral scholars

Survey Name	Description
Survey of Earned Doctorates (annual)	Provides information about new doctorate recipients with post-graduation commitments for employment or study. Postdoctoral appointments are counted as "study" for this purpose. Summary data tables are publicly available.
Survey of Doctorate Recipients (biennial)	1993 and 1997 surveys asked if current job is a postdoctoral appointment. 1999, 2001, 2003, and 2008 ask if job was a postdoc and reasons for taking the postdoc. 1995 and 2006 asked respondents if current job is a postdoctoral appointment, number of postdocs held, and details about up to 3 postdocs. In 1993 an indicator of whether the position is a postdoc is available for public use. Other data about postdocs available only in restricted use dataset.
Survey of Graduate Students and Postdoctorates in Science and Engineering (annual)	This survey of U.S. academic institutions provides aggregate data on the number and characteristics of postdoctoral scholars.

Motivational factors

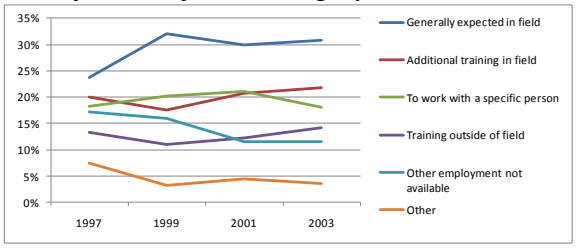
Perhaps the most straightforward motivation for taking a postdoctoral appointment is a desire for an academic career. However, it might be useful to examine this motivation more carefully and distinguish it from other motivations such as interest in a research career that is not necessarily academic, belief that a postdoctoral appointment is a prerequisite for a desired career, or a motivation to change direction after completing the doctorate.

The National Science Foundation's (NSF) Survey of Doctorate Recipients asks scientists who have taken postdoctoral appointments their reasons for becoming a postdoc. Trends in these survey responses from 1997-2003 are shown in Figure 1. The most commonly reported reason for becoming a postdoc is that it is expected for one's career. A lack of other employment opportunities is less frequently reported and has become less frequent over time.

Interest in an academic career. Postdoctoral appointments have long been associated with the intention to pursue an academic career in the form of a tenure-track academic appointment (Curtis and National Research Council, 1969). More recent studies have also found this association (Fox and Stephan, 2001). Taking a *post hoc* view, those who become tenured faculty are more likely to have held a postdoctoral appointment than scientists who follow other career paths (Zumeta, 1985).

Proposition 1: Aspiration to an academic career will be positively associated with becoming a postdoc.

Figure 1
Primary reasons for becoming a postdoc.



Source: Survey of Doctorate Recipients data from SESTAT Metadata Explorer.

Taste for science. Postdoctoral appointments may also attract those who aspire specifically to a research career. Akerlind found that Australian postgraduate researchers often described their career aspirations in terms of research rather than faculty appointments (Akerlind, 2005, Akerlind, 2009). Recent work has found that an intrinsic motivation or taste for science can have a strong influence on scientists' career choices (Roach and Sauermann, 2010, Stern, 2004). Such intrinsic motivations were found to be stronger in fields where postdoctoral appointments are common, such as the life sciences (Zumeta, 1985).

Career theory suggests that value motivation, such as taste for science, along with self-direction, may differentiate between those who persist in careers in science and research from those who are more likely to pursue careers in education and health fields (Briscoe and Hall, 2006, Segers et al., 2008). The role of taste for science may also be interpreted from the perspective of needs-supplies fit, in that scientific careers fulfill a perceived need for a work environment consistent with scientific

values (Edwards, 1991). While work on values congruence has usually focused on person-organization fit (Edwards and Cable, 2009), the concept could potentially be applied to occupational choice (Blau et al., 1956). Scientists may be willing to make financial and other sacrifices to be scientists because the scientific occupation, rather than the employing organization, is congruent with their values. While prior studies have not addressed this question specifically, these considerations suggest that those with an intrinsic motivation or taste for scientific research are more likely to become postdocs.

Proposition 2: Taste for science will be positively associated with becoming a postdoc.

Belief that postdoc positions are required. Some new PhDs become postdocs because they feel that a postdoctoral appointment is required or expected in their field (Curtis and National Research Council, 1969). Prior research suggests that doctoral students' beliefs about career prospects are influential even when they are only partially aligned with actual career paths typical in their field (Fox and Stephan, 2001). As shown in Figure 1, this is the most commonly reported reason for becoming a postdoc reported by respondents to the Survey of Doctorate Recipients. This reason showed an upward trend between 1997 and 1999 and has decreased only slightly in the subsequent two surveys.

Proposition 3: The belief that postdoctoral appointments are required will be positively associated with becoming a postdoc.

Changing fields. Taking a postdoctoral appointment may also be associated with the desire or perceived need to change fields (Curtis and National Research Council, 1969, Libarkin and Finkelstein, 2001). The desire to obtain training in another field was cited in one study as a motivating factor by over 40% of biochemists who had taken postdoctoral appointments (Nerad and Cerny, 1999). Changing research interests could motivate a scientist to change fields. Speculatively, those scientists who found themselves in a less engaging area of study during the doctoral program may use the postdoctoral appointment as a way to transfer their skills to a more interesting type of research, assuming that they are still interested in a research career.

Proposition 4: Finding current research interesting will be negatively associated with becoming a postdoc.

Human capital

Human capital may play a role in the motivation to become a postdoc in two ways. First, employers may select scientists based on the level of human capital upon completion of the doctorate. These selection decisions may influence who becomes a postdoc. Second, scientists themselves may perceive the postdoctoral appointment as an opportunity to further develop their human capital.

Human capital theory initially focused on the additional knowledge and skills gained through education (Becker, 1975). In the extension of this theory to the concept of science and technology (S&T) human capital, knowledge and skills are supplemented with tacit knowledge, social capital, and connections to scientific networks to better explain the role of research experiences in developing scientific capacity (Bozeman et al., 2001). Human capital is thought to be more successfully developed when the person is well-matched to the position or occupation (Jovanovic, 1979, McCall, 1990) and this results in increased productivity and other positive labor market outcomes (Allen and van der Velden, 2001, Bender and Heywood, 2009).

Level of human capital. One implication of human capital theory is that the scientists with the most human capital upon completion of the doctorate will be able to secure the most desirable positions. Relatively low pay and low job security imply that postdoc appointments would be less desirable positions. Some scientists, generally considered to be of lesser ability, may find themselves in postdoctoral appointments for an extended period of time and unable to secure a career position (Puljak and Sharif, 2009).

However, the further implication that the most capable scientists are more likely to find career positions and avoid postdoc appointments is generally not supported and may be overly simplistic. Scientists of high ability also take postdoctoral appointments (Hornbostel et al., 2009, Zumeta, 1985, Bohmer and Von Ins, 2009). The role of mobility and networks in development of S&T human capital may make postdoc appointments desirable, especially to those high-ability scientists who expect high productivity in an appointment that is a close fit to their research interests.

Several previous studies using measures that would seem to be good proxies for ability, such as pre-doctoral publications, have failed to find an effect on the probability of becoming a postdoc (McGinnis et al., 1981, Reskin, 1976, Su, 2009). There are four possible interpretations. One is that

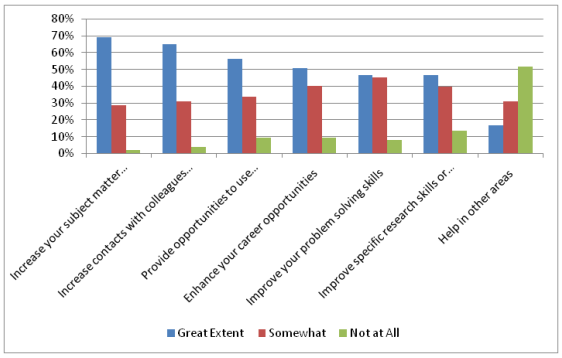
prior studies have not had adequate ability measures. Another explanation is that ability plays no significant role in determining who becomes a postdoc. A related interpretation is that the effect of ability depends on time period, discipline, or other factors; prior studies examined widely varied contexts. Finally, it is possible that this relationship is nonlinear, with high ability doctorate recipients becoming postdocs by choice for the opportunity to develop S&T human capital and lower ability doctorate recipients becoming postdocs by necessity (Zumeta, 1985). The failure of prior empirical work to demonstrate a consistent relationship between ability and becoming a postdoc suggests the following speculative proposition.

Proposition 5: Both high and low ability will be positively associated with becoming a postdoc relative to average ability.

Development of human capital. New doctorate recipients may see postdoctoral appointments as not only a way to acquire human capital, but also a valuable way to signal their ability through the norms of open science (Dasgupta and David, 1994). This explanation is consistent with the high level of academic publishing achieved by many postdocs (Cheung, 2008, Corley and Sabharwal, 2007, Kyvik and Olsen, 2008). Dasgupta and David suggest that even scientists who eventually want to work in industrial settings where secrecy is the norm may seek postdoctoral appointments that allow them to establish a track record of publications.

However, the literature has discussed development of generalist skills more than the types of specific scientific capabilities or technical skills that would be signaled through academic publications. This is somewhat surprising, since scientists themselves report subject matter knowledge as the greatest benefit from their postdoctoral appointments (See Figure 2). A number of concerns have been expressed about knowledge and skill development. Postgraduate researchers in Australia reported that the skills they were developing were targeted toward faculty positions that combined research and teaching, but that these positions were scarce and the postdocs were often more interested in pure research positions (Akerlind, 2009). Some of these Australian postdocs did not consider themselves to be in training at all. It is also not clear whether postdoctoral appointments serve the purpose of further developing scientists' abilities. If these appointments are holding patterns or signals (Mishagina, 2009, Recotillet, 2007), it would not make sense for graduates to become postdocs as genuine skill-development measures.

Figure 2
The extent to which biological scientists responding to the Survey of Doctorate Recipients said that their most recent postdoctoral appointment had the following benefits. The exact question was "To what extent did your most recent (or current) postdoctoral appointment …"



Source: 2006 Survey of Doctorate Recipients data from SESTAT Data Tool.

In practice there has been a significant effort to improve skill development opportunities for postdocs, especially in the areas of generalist skills such as project management, communication, and proposal writing (Davis, 2009). Studies have also found that those who complete a PhD quickly may be more likely to become postdocs (Recotillet, 2007, National Research Council, 1981, Laudel and Gläser, 2008). If postdoctoral appointments have value for skill development, they may have greater appeal to students with less developed skill levels. Here skill does not refer to achievement measures, such as publications, or inherent ability, but to skills such as teamwork, project management, and communication usually acquired through professional experience. Although there are other possible explanations, the finding that increasing age reduces the chance of becoming a postdoc is consistent with this line of reasoning (Zumeta, 1985, McGinnis et al., 1981, Recotillet, 2007). Alternatively, students without these skills may not be competitive for career positions, and so may find themselves in postdoctoral appointments by default.

Stephan and Ma express concern that human capital is not put to its highest use during the extended postdoctoral periods that have become typical (2005). In combination with the emphasis on generalist skills, this concern suggests that the first post-doc may be the most valuable to augmenting human capital. Mishagina found that scientists who had multiple postdoctoral appointments were more likely to leave science and engineering, indicating that these subsequent positions served as waiting lists rather than skill-

developing opportunities (2009). It may make sense to differentiate between postdocs in their first appointment, when they are likely to be developing new generalist skills, from those in subsequent appointments. Generalist skills receive a lot of attention in qualitative and practitioner-oriented work, but there appears to be little known about their specific place in scientific training and careers. The following proposition could be tested to increase our understanding of the role of generalist skills.

Proposition 6: Opportunities to develop generalist skills during the doctoral program will be negatively associated with becoming a postdoc.

The postdoctoral appointment may also be an important stage in the transition from student to independent researcher (Laudel and Gläser, 2008). Two aspects of becoming an independent researcher are selecting research topics and obtaining grant funding. Although the sample was small, one study found that PhD students whose advisors had assigned their dissertation topics were more likely to become postdocs (Curtis and National Research Council, 1969). Surveys of postdocs reveal that proposal-writing is a key skill they hope to develop during their appointments (Davis, 2009, Chang et al., 2005, Helbing et al., 1998a). These findings suggest that doctoral students who have had experiences with selecting research topics and obtaining funding may be less likely to become postdocs, as they will perceive fewer new skills to gain from the experience.

Proposition 7: Prior experience in selecting their own research projects and obtaining grant funding will be negatively associated with becoming a postdoc.

Postdoctoral appointments have been used to examine the extent to which universal and meritocratic norms prevail in science, as opposed to particularist norms that judge scientists and their work based on demographic characteristics (Reskin, 1976, Long and Fox, 1995). Demographic factors that have been studied with regard to their relationship to postdoctoral appointments include gender, race, nationality, age, and discipline. Nationality may also moderate the effects of

gender and discipline. While demographic characteristics are not typically interpreted causally, they often indicate where particularist norms or social roles influence outcomes.

Gender. Of these demographic characteristics, the most extensively studied has been gender. However, many studies fail to find significant differences between women and men in the probability of becoming a postdoc (Zumeta, 1985, Recotillet, 2007, National Research Council, 1981, Helbing et al., 1998b). Nolan et al. found that women chemists were less likely to become postdocs (Nolan et al., 2008). However, many more studies indicate that gender has an effect through interaction with marriage (Zumeta, 1985, Curtis and National Research Council, 1969, National Research Council, 1981), children (Martinez et al., 2007), and spousal employment (Helbing et al., 1998b). These interaction effects may be stronger for foreign-born scientists (Martinez et al., 2007). However, even the interaction effects are ambiguous in direction. One possible explanation is that in some cases women who have family constraints take postdoctoral appointments instead of career jobs. In other cases, they may forego postdoctoral appointments due to family constraints. Women of higher scientific ability might be more likely to find themselves in the first situation and women of lesser ability in the second. It seems prudent to control for gender and its interactions with marriage and children.

Proposition 8: Gender *per se* will not have a direct effect on the probability of becoming a postdoc. Studies that aim to explain the role of gender in postdoctoral appointments should include other variables that are likely to be relevant, such as marital status and parenthood.

Race. Although one study found that U.S. underrepresented minorities (African-Americans, Hispanics, and Native Americans) were less likely to become postdocs, possibly due to the greater availability of alternative employment at higher pay (Zumeta, 1985), more studies conducted over 30 years have failed to find an effect by race (National Research Council, 1981, Fiegener, 2009, Thurgood et al., 2006). The most common finding, especially in more recent studies, has been that race does not influence the probability of becoming a postdoc for underrepresented minorities. However, analysis of racial effects is limited by the small number of minority postdocs identified in even large surveys. Qualitative methods may be more appropriate.

Proposition 9: The probability of becoming a postdoc will not be significantly affected by U.S. underrepresented minority status.

Nationality. For the many graduate students from outside the U.S., there are also motivations related to the opportunities, incentives, and institutions surrounding scientific career paths in their home countries. Existing research in this area has focused on broad classifications, such as visa status and developing country origins. Students

from developing countries have been found to be more motivated to stay in the U.S. because their earnings potential, even as a postdoc, is much higher in the U.S than in the home country (Lan, 2009). Developing countries may also have other undesirable characteristics, such as lack of facilities, isolation, and undesirable political and social conditions (Commitee on Policy Implications of International Graduate Students and Postdoctoral Scholars in the United States and Board on Higher Education and Workforce, 2005).

Doctoral students from some regions and countries are more likely to stay in the U.S. after completing their degree (Thurgood et al., 2006, Finn, 2010). The NSF data analyzed by Thurgood show that doctoral scientists from Europe and Asia are more likely to stay than those from other regions. Within those regions, graduate students from China, India, and Russia are most likely to stay in the U.S. Since postdoctoral appointments take place primarily in the U.S., it seems likely that those who are more likely to stay are also more likely to become postdocs.

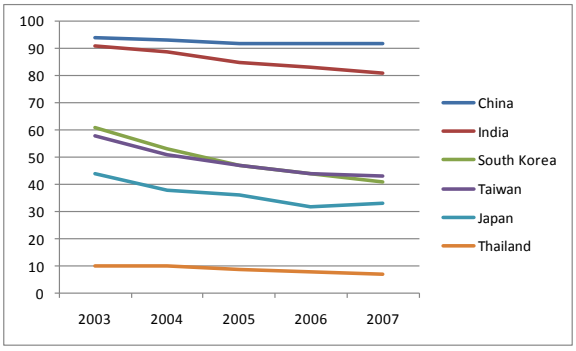
On the other hand, some scientists who have opportunities for attractive scientific careers at home may be less likely to become postdocs in the U.S. This may be especially true if, as described by Holzinger (2007), the opportunities in their home country are tied to native-language publications and national professional associations, as is common in continental Europe. Graduate study in the U.S. may fulfill a home country expectation for international study and preclude the need for or benefit from being a postdoc in the U.S.

Figures 3-6 present stay rates for doctorate recipients by country grouped to illustrate regional patterns, which may correspond to career incentives. Figure 3 illustrates the considerably higher stay rates for new PhDs from the large, rapidly developing Asian nations of China and India compared to the lower stay rates for those from smaller Asian nations.

Figure 4 shows the stay rates for new PhDs from Anglo-Saxon and other European nations. The stay rates appear noticeably higher for Eastern Europe, but the pattern for Anglo-Saxon and continental nations is not clear. Figure 5 shows only the UK, Australia, Canada, and the continental European nations. Consistent with Holzinger's (2007) distinction between Anglo-Saxon and continental European models, France, Germany, and Spain do have lower stay rates. Greece, which might be expected to follow the same pattern, starts out with a higher stay rate but has decreased to a low rate within four years. Italy's higher stay rates may reflect barriers to reintegration into the Italian science community (Gill, 2005). The UK, Canada, and Australia all have high initial stay rates, but Canadian and Australian stay rates drop sharply after the second or third year. This pattern is consistent with a postdoctoral appointment in the US followed by return to the home country or relocation to a third country. Disaggregated data for The Netherlands and Scandinavian nations, hypothesized to follow the Anglo-Saxon model, would help confirm the pattern. Qualitative and policy research would be useful to understand apparent outliers like Italy and Greece.

Figure 3

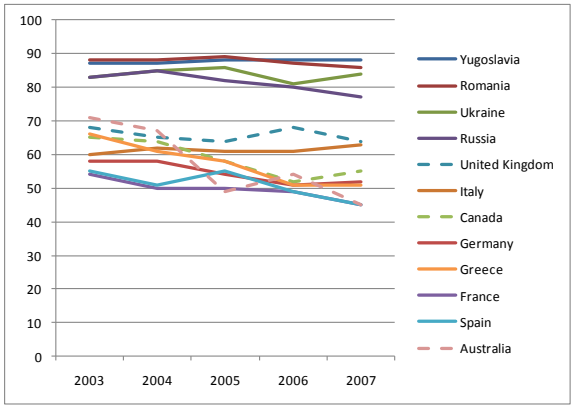
Stay rates for 2002 temporary resident science and engineering doctorate recipients from Asian nations.



Source: Adapted from Finn, M. G. (2010). Stay rates of foreign doctorate recipients from US universities, 2007 (pp. 33). Oak Ridge, Tennessee: Oak Ridge Institute for Science and Education.

Figure 4

Stay rates for 2002 temporary resident science and engineering doctorate recipients from Anglo-Saxon nations (dashed lines) and European nations.



Source: Adapted from Finn, M. G. (2010). Stay rates of foreign doctorate recipients from US universities, 2007 (pp. 33). Oak Ridge, Tennessee: Oak Ridge Institute for Science and Education.

Figure 5
Stay rates for 2002 temporary resident science and engineering doctorate recipients from Anglo-Saxon (dashed lines) and continental European nations.

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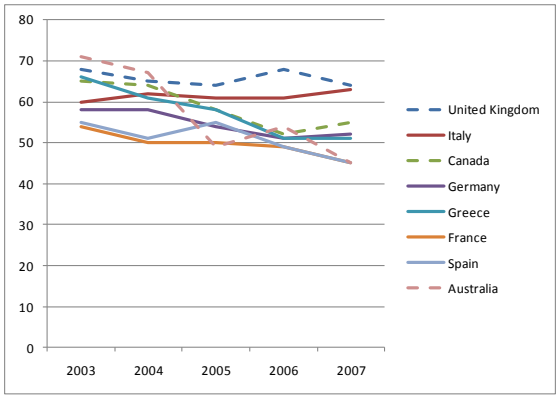
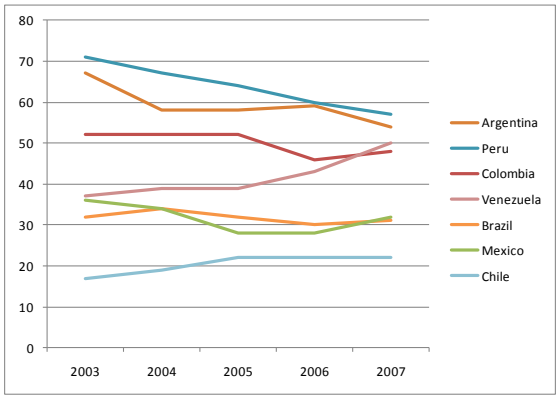


Source: Adapted from Finn, M. G. (2010). Stay rates of foreign doctorate recipients from US universities, 2007 (pp. 33). Oak Ridge, Tennessee: Oak Ridge Institute for Science and Education.

Figure 6
Stay rates for 2002 temporary resident science and engineering doctorate recipients from Latin American nations.



Source: Adapted from Finn, M. G. (2010). Stay rates of foreign doctorate recipients from US universities, 2007 (pp. 33). Oak Ridge, Tennessee: Oak Ridge Institute for Science and Education.

Figure 6 shows stay rates for Latin American countries. New PhDs from Argentina and Peru have higher stay rates than those from other parts of Latin America. Disaggregated data on more Latin American and developing nations as well as qualitative research could lead to a better understanding of the career incentives and institutions shaping the decisions of Latin American scientists. Notably, Brazil has a much lower stay rate than the other BRIC nations.

The relationship between staying in the US and becoming a postdoc is likely to be endogenous, with those who stay more likely to become postdocs and those who become postdocs more likely to stay. The more interesting question is about how the underlying structure of national innovation systems and scientific and academic careers in the home country influences the decision of foreign scientists to pursue a career in the US. Quantitative data document national patterns of immigration and economic motivations have been demonstrated empirically. However, little is known about qualitative and institutional aspects of international postdocs and the approach to such questions is largely speculative at this time.

Proposition 10: Regional patterns of institutions and incentives associated with scientific careers and other home-country political, cultural, and economic characteristics will be systematically associated with the probability of becoming a postdoc, with students from small Asian, continental European, and most Latin American nations being less likely to become postdocs.

Foreign students from different disciplines vary in their likelihood of remaining in the U.S. after completing the PhD (Commitee on Policy Implications of International Graduate Students and Postdoctoral Scholars in the United States and Board on Higher Education and Workforce, 2005). This finding can be attributed to the demand for specific expertise in the U.S. and the quality of the U.S. science in those disciplines. Conversely, demand for specific skills in foreign students' home countries will also play a role. Since the U.S. is the primary location of postdoctoral appointments, it seems likely that foreign students in disciplines that are in greater demand in the U.S. will be more likely to become postdocs.

Proposition 11: For non-U.S. doctoral students, the stay rate for students in a particular discipline will be positively associated with becoming a postdoc.

Nationality may also interact with gender. U.S. native male scientists may be particularly unlikely to become postdocs due to motivation or opportunity to pursue more highly paid opportunities within and outside of academic science (Black and Stephan, 2008). Martinez et al. (2007) also found an interaction between nationality, gender, and marriage, with married men from the U.S. being less likely to make accommodations for a spouse's career. This somewhat surprising finding may relate to cultural differences, the fact that non-US respondents had already made the decision to study in a foreign

country, or possibly non-US respondents not being sure how to answer the question if the spouse did not have a career. It seems likely that the findings by Martinez et al. would generalize beyond the NIH sample they studied and to the postdoctoral career stage.

Proposition 12: Nationality, gender, and marital status will interact such that married men from the US are least likely to become postdocs.

Empirical evidence supports the role of temporary visa status as an indicator associated with postdoctoral study, independent of the effect of nationality (Lan, 2009). Permanent visa status confers a number of advantages to a job seeker that increase the probability of receiving a career position rather than a time-limited postdoc appointment.

Proposition 13: Temporary visa status will be positively associated with becoming a postdoc.

Age. Older doctorate recipients have been found to be less likely to become postdocs (Zumeta, 1985, Recotillet, 2007), usually interpreted to indicate that older PhDs are more likely to have financial obligations that motivate them to take higher-paying positions. However, one study found this relationship to apply only to fellowships and not to research associate postdocs hired with grant funding (McGinnis et al., 1981).

As discussed earlier, opportunities to develop generalizable skills may be negatively associated with becoming a postdoc. New PhDs who had work experience before entering their doctoral program or who spent more time as doctoral students may have had more of these opportunities. Since work experience and additional years of study both take time, they are likely to be correlated with age and may mediate the effect of age, at least partially. Age has been found fairly consistently to be negatively associated with becoming a postdoc, although the mechanism of its effect is not yet clear.

Proposition 14: Age will be negatively associated with becoming a postdoc. Prior work experience and time to degree will mediate the effect of age on likelihood of becoming a postdoc.

Discipline. The most straightforward way discipline has been related to the probability of becoming a postdoc is through labor market conditions. Postdoctoral appointments are frequently interpreted as a response to a lack of career opportunities, especially in academia (Stephan and Ma, 2005). Graduate students who perceived a lack of career opportunities might be more likely to plan to become postdocs, and graduates who actually encounter a lack of career opportunities might be more likely to in fact become postdocs. The relationship between perceived and actual career opportunities was explored by Fox and Stephan (2001). While the most obvious way to study labor market effects would be observing longitudinal trends, it might also be possible to observe this effect by discipline, if there is variation in the labor markets for different disciplines. Such differences in job opportunities may be observable at the level of specific fields within broad disciplinary groupings like life sciences.

Proposition 15: A large number of new doctorate recipients relative to the number of academic positions available will be positively associated with becoming a postdoc.

Postdoctoral appointments are more likely in some fields than in others. In addition to labor market factors, this may also be due to the type of knowledge involved in that specific field. At the most basic level, this has been attributed to some fields having more material to master (Curtis and National Research Council, 1969). More specifically, postdoctoral appointments may be more likely the more highly specialized the field or closely tied to biological systems (National Research Council, 1981). Biochemistry has long had a particularly high prevalence of postdoctoral appointments (Nerad and Cerny, 1999), possibly due to its inherent connection to two disciplines. Postdocs may also be more common in pure sciences like chemistry or physics than in transfer fields where basic and applied work are integrated, such as computer science and mechanical engineering (Zubieta, 2009).

There have been numerous attempts to create conceptual maps of science. It might be possible to use such a map to predict the effect of scientific discipline on the paths of scientific careers, including the prevalence of a postdoctoral career stage. Klavans and Boyack (2009) have synthesized prior approaches to create a consensus map of science. They place biochemistry at one end and mathematics and computer science at the other. This configuration is consistent with the relative prevalence of postdoctoral appointments in those fields—with high prevalence in biochemistry and low prevalence in math and computer science.

It is also possible that the timing of specific scientific discoveries could make postdoctoral appointments particularly desirable (Kuhn, 1962, Stephan and Levin, 1992). Breakthroughs or paradigm shifts within a field could make a postdoctoral appointment an opportunity for a scientist to become one of the first in a new

regime rather than one of the last trained under an old regime. This is a speculative area of inquiry, but could potentially lead to rich models of how knowledge structures relate to the structures of careers and professions.

Proposition 16: The knowledge content of scientific disciplines will be related to the prevalence of postdoctoral appointments in that discipline in a predictable way, such as through complexity, specialization, or change.

Alternatively and more concretely, postdoctoral appointments could address a mismatch between doctoral training and existing job opportunities. For example, a biochemist might seek a postdoctoral appointment that develops skills in biomedical engineering. This situation could be more likely to result when training takes place in disciplinary departments but job opportunities are in interdisciplinary settings (Chang et al., 2005). This leads to the hypothesis that the motivation to change fields may be rationally motivated by labor market conditions. This motivation is not mutually exclusive with changing research interests. Data about career patterns of recent graduates would allow for a test of the following proposition.

Proposition 17: Being in a field where recent doctoral graduates have frequently changed fields will be positively associated with becoming a postdoc.

University

Studies of university-level factors influencing postdoctoral appointments have most frequently emphasized the role of prestige. However, other features of the doctoral institution may also influence the likelihood of becoming a postdoc.

Prestige. Perhaps because the scientific enterprise is highly stratified, prestige is the most widely studied university-level characteristic associated with postdoctoral appointments. In this context, stratification means the structure of the scientific enterprise and the relative prestige and influence of its parts. One of the most fundamental ideas in the study of stratification of science is the theory of cumulative advantage, often referred to as the "Matthew effect" (Merton, 1968). Cumulative advantage refers to the tendency for scientists who have already achieved recognition to have an advantage over unknown scientists in achieving future recognition. This leads to a concentration of prestige in a small number of scientists and institutions.

Psychological, cultural, and structural mechanisms of cumulative advantage were proposed by Cole and Cole (1973). Rosen proposed an alternative model of stratification based on high returns to small increments in ability at the top of the ability range (Rosen, 1981). While different mechanisms have been proposed, all of these models address the observation that science is highly stratified with prestige and influence concentrated among a few top individual and institutional contributors.

Several studies have found that new PhDs from more prestigious universities were more likely to become postdocs (Zumeta, 1985, Curtis and National Research Council, 1969, Zumeta, 1984). However, Curtis found that the relationship with prestige was weaker in biological sciences and Zumeta found that the relationship grew weaker over time. It is possible that this relationship will not hold for a life sciences sample today, but the relationship has been common enough in other studies that the hypothesis should be tested. Further, while prestige may be found not to be a strong predictor of which life sciences doctorates become postdocs, prestige of the doctoral institution is known to have strong effects on other career outcomes for scientists (Su, 2009, Zubieta, 2009, Bedeian et al., 2010, Burris, 2004). Burris suggests that a more prestigious postdoctoral institution may take the place of the doctoral institution in explaining future career outcomes.

A strong role for prestige is also supported by the finding that predoctoral publication productivity typically does not predict postdoctoral appointments (Hornbostel et al., 2009, McGinnis et al., 1981, Su, 2009), although Reskin (1976) found it predicted prestigious postdoctoral fellowships for men only. Productivity is one of the most plausible alternative explanations to prestige, but evidence for its effect is weak. A direct effect of prestige on funding decisions does not seem to be the mechanism through which prestige influences later outcomes. Like many other studies of peer review cited by Bornmann and Daniel (2006), Viner et al., (2004) do not find that prestige of the doctoral or proposed postdoctoral institution had an effect on funding decisions. While the mechanism is uncertain, prior research generally supports the idea that graduates from prestigious universities will be more likely to become postdocs. There is significant empirical support for the following proposition.

Proposition 18: University prestige will be positively associated with becoming a postdoc.

Features of the doctoral institution. There has been considerably less attention paid to the role of features of the doctoral institution other than prestige. For example, the current literature does

not seem to address the effect that interaction with postdocs as a graduate student might have on the probability of becoming a postdoc. Few studies have examined features of the doctoral institution or program, so initial hypotheses about their influence on postdoc appointments of their graduates are speculative.

It is common for doctoral students and postdocs to work together in labs and for postdocs to play a role in training and supervising graduate students (Akerlind, 2005, Vogel, 1999). Institutions that make extensive use of postdocs themselves might produce graduates who are more aware of opportunities for postdoctoral appointments or to consider such appointments an expected part of the research career.

Proposition 19: Graduate students at universities where there are many postdocs may be more likely to become postdocs themselves.

The nature of doctoral student-postdoc interactions as well as their frequency may influence attitudes toward postdoctoral appointments. Conditions for postdocs vary a great deal from campus to campus (COSEPUP, 2000). It seems likely that doctoral students at universities where postdocs are generally satisfied with their appointments would be more likely to become postdocs themselves. This is a potentially interesting question in particular because universities are putting structures in place to improve conditions for postdocs and incorporate them into the university community, sometimes as a result of postdocs' organizing activity (Gerwin, 2010). These structures might further institutionalize the postdoctoral career stage by increasing demand for postdoc positions among their own graduates. Postdoctoral organizing activity and administrative oversight are relatively new phenomena, so there is not yet empirical support for specific hypotheses about their effects.

Proposition 20: The likelihood of becoming a postdoc will be positively related to the level of satisfaction of postdocs at the doctoral institution.

Postdoctoral scholars are highly concentrated in prestigious universities that receive large amounts of research funding (National Science Foundation, 2007, National Science Foundation, 2010). These universities are in turn geographically concentrated, especially in Boston and the Bay Area. Postdoctoral appointments can play different roles in scientific careers. For some, they may expand networks beyond the doctoral program. For others, they may provide an opportunity to work in one's field of study that is compatible with personal obligations, such as a spouse's career (Martinez et al., 2007). New PhDs from universities in metro areas with many postdocs at multiple institutions may be able to accomplish both of these goals at the same time. On the other hand, graduates of universities that are not located in college clusters would need to relocate, perhaps half-way across the country, for a time-limited position. These geographic considerations imply that postdoctoral appointments may be more common for students when there are many such opportunities available at other institutions in the local area.

Proposition 21: The likelihood of becoming a postdoc will be positively related to the number of postdoctoral appointments available in the local area.

Based on interviews of Australian researchers, Laudel & Glaser (2008) propose that postdoctoral appointments may represent a market failure in which some universities are free-riders, producing doctoral graduates who have not been fully prepared. These students are then more likely to take postdoctoral positions because they need to remedy deficits in doctoral training. We might expect this phenomenon to manifest itself more strongly in departments where faculty members emphasize research over teaching and where the average number of years to earn a degree is low.

Proposition 22: The likelihood of becoming a postdoc will be inversely related to the focus on teaching and mentoring in the doctoral program.

Cross-level interactions

Individual-level factors may interact with university-level factors to make a postdoc position more or less likely. While research on such interactions has been limited, the literature does suggest some likely possibilities. This section briefly considers three such potential interactions.

Ability and prestige

Scientific careers are characterized by cumulative advantage (Merton, 1968). This implies that outcomes will be better for those who combine multiple advantages, such as ability and affiliation with prestigious institutions. In discussing the hypothesized relationship between ability and the likelihood of becoming a postdoc, a nonlinear relationship seemed likely, with those of highest and lowest ability most likely to become postdocs. Non-linear institutional effects have been found in the life sciences (Smith-Doerr, 2006). Perhaps those students who combine high ability with high prestige doctoral institutions will be most likely to become postdocs, as will those of low ability at low prestige universities. In studying a sample of mid-to-high prestige institutions, we might expect

those high ability students at high prestige schools to be the most likely to become postdocs. Cumulative advantage is well-established in the sociology of science, lending support to the following proposition.

Proposition 23: Individual ability and institutional prestige will interact such that high ability individuals at high prestige institutions are most likely to become postdocs.

Citizenship and location

Foreign graduate students are at a disadvantage in their ability to tap into informal labor markets in the U.S.(Wei et al., 2009). In discussing the relationship between location of the doctoral institution and the likelihood of becoming a postdoc, it seemed that proximity to postdoctoral opportunities would increase the probability of becoming a postdoc. This effect may be stronger for non-U.S. students. The concentration of postdocs on the coasts, where immigrant populations are also concentrated, may also contribute to this effect. While postdocs are clearly concentrated on the coasts, and there is empirical evidence of their disadvantage in the labor market, at this point propositions about the interactions of those factors are speculative.

Proposition 24: Location of doctoral institution and citizenship will interact in such a way that non-U.S. students in doctoral programs far from other postdoc opportunities will be least likely to become postdocs.

Gender and location

Postdoctoral appointments may be especially desirable when they combine the ability to affiliate with a new institution with the ability to stay in the same geographic location. This effect may be stronger for women, since they are more likely to seek an appointment that is compatible with a spouse's career (Nerad and Cerny, 1999). Prior research has identified the propensity for women scientists to concentrate in college clusters (Kulis and Sicotte, 2002). We may be able to generalize from these factors known about women's careers to the context of postdoctoral appointments.

Proposition 25: Location of doctoral institution and gender will interact such that women in locations where there are many postdoctoral appointments will be most likely to become postdocs.

Conclusion

Research about why new doctorate recipients become postdoctoral scholars identifies influences at the individual and university levels. A better understanding of which graduate students become postdocs would be of value to those who employ, fund, and organize postdocs.

While we have information about trends in certain key motivations for postdoctoral appointments (see Figure 1), the information about motivations is still fairly superficial. Because the demographic variables that have been the focus of most prior research about why people become postdocs serve as indicators but don't explain mechanisms, it would be beneficial for future research to explore some potential mechanisms behind this career choice. For example, future research could examine the relative importance of knowledge acquisition and network development in the choice of a postdoctoral appointment. Further, it would be useful to advance our understanding of the role that home country career incentives and institutions play in the decisions of international graduate students about whether to become postdocs in the U.S. While higher earning potential in the U.S. explains many developing-country nationals' decisions to stay, we know less about why some choose to return and the decisions made by scientists from developed countries. A third individual perspective to consider for future studies is the influence of personal characteristics such as taste for science, disposition, and knowledge of career options.

Another potentially interesting direction for individual-level research would be to examine which scientists benefit from becoming postdocs. Scientists report many benefits from postdoctoral appointments (see Figure 2), but these self-reported benefits, primarily in specialized knowledge, are not clearly tied to outcomes. For example, studies have suggested that the prestige of a postdoctoral institution could take the place of the doctoral institution in determining future career opportunities.

It would be useful to test this explicitly, as well as whether the postdoctoral institution served as a more accurate signal of future potential than the doctoral institution. The concept of taste for science could potentially be employed to assess the benefits of becoming a postdoc. By providing a way to approximate the value of the non-monetary rewards of scientific careers in monetary terms, both monetary and non-monetary benefits could be considered in evaluating career outcomes from postdoctoral appointments.

University-level influences beyond prestige are also a fruitful area for future study. We know little about how characteristics of doctoral programs influence who becomes a postdoc. Factors such as location, teaching and mentoring of doctoral students, interaction with current postdocs, and career placement services may influence who becomes a postdoc.

The choice of research questions at both the individual level and the university level should be guided by a consideration of which elements could potentially be influenced by policy. Policy interventions could be designed to encourage those most likely to benefit from postdoctoral
appointments to pursue them, and to do so with accurate information about how to seek an appropriate appointment and to maximize the opportunity it provides. Targeted interventions to provide the right information to doctoral students at the right time could improve decision making and utilization of resources during the doctoral and postdoctoral years.

Appendix
Empirical studies of postdoctoral scholars

Author and date	Subjects	Data	Methods	Key findings	Limitations
Akerlind, 2005	22 postdoctoral researchers and 10 supervisors at 5 top-8 Australian universities.	Semi-structured interviews	Content analysis	Career development support is focused on academic and pure research careers and is not systematic and institutionalized. Other career paths are seen as failures. After 5-6 years as a postdoc there is a sharp drop in employability	Exploratory. Set in Australia. Supervisors available for interview may represent biased sample.
Akerlind, 2009	1,011 PDRs from 38 Australian universities, 22 PDRs from Australian top-8 universities, and 10 supervisors at those same top schools.	Online survey results and interview transcripts	Online survey and in-depth interviews	Many PDRs define their career goal as a research career rather than an academic career, do not see the PDR as an interim step, already feel they are doing independent research, and engage in significant non-research activities, especially supervision.	Exploratory. Set in Australia. Does not consider gender or national origin.
Black and Stephan, 2008	Authors of 267 Science Research Articles and Reports published 11/2/2007-5/2/2008.	Broad field of research, # of authors, name of each author, institution, location, academic position, affiliation, usually from web page of last author's lab. Melissa data on ethnicity of names.	Cross tabulations and descriptive statistics.	Establishes the strong roles played by non-US postdocs and grad students in US research based on publication records. 86.5% of *Science* articles have at least one postdoc or student as an author. 74.6% of the first authors located in the US are postdocs or students. 59% of postdoc authors have non -English/European names.	Descriptive. Assumptions about authorship order and name-based classification of researchers by ethnicity.
Bohmer and Von Ins, 2009	Applicants for Emmy Noether fellowships 1999-2006	Peer review documents for 48 applications, bibliometric analysis, 462 online survey responses, 21 interviews	Triangulation, bibliometric, online survey, interviews, document review	Evaluation of the Emmy Noether fellowship program.	Findings relate to a specific, highly prestigious German fellowship program. Successful and rejected applicants were uniformly highly qualified.

Author and date	Subjects	Data	Methods	Key findings	Limitations
Bornmann and Daniel, 2006	30% of 1,954 doctoral and 743 postdoctoral fellowship applicants, 1985-2000. Prestige data analyzed only for those moving within Germany, and for shorter time span.	Archival data from fellowship applications. German research foundation data on universities. Rankings.	Chi-square tests, Cramer's V, monte carlo	BIF more likely to award doctoral and postdoctoral fellowships in basic biological research rather than clinical medicine, consistent with its mission. The use of categorical variables and German subsample may have compromised power and biased the study.	Only analyzed the 30% of doctoral applications both coming from and going to a German university. Only analyzed postdoc data through 1995. Use of categorical measures for continuous variables. Field-based selection interpreted as bias more than mission.
Bryson, 1998	Over 400 contract research staff at 10 UK universities. CRS at one UK university. Directors of Personnel in all UK HEIs.	Survey data of CRS at 10 universities. Administrative data from 1 university. National statistics, job ads for CRS in 1996, preliminary results from survey of Directors of Personnel.	Qualitative summary of survey results.	Describes features of CRS system in the UK. The author believes the main root causes of problem are weak academic union involvement and institutional inertia.	Data collected in the UK 1994-1998. Article has a strong advocacy tone.
Burris, 2004	Full-time faculty members listed in American Sociological Association's *Guide to Graduate Departments of Sociology* (1995)	For each faculty member, school where PhD was received.	Cross tabulations and expected frequencies in matrix.	Prestige is very stable due to the self-replicating nature of social capital. The self-replicating behavior usually happens under the guise of universalism and meritocracy. "The more common pattern among the lucky few who have been able to parlay a PhD from a non-top 20 department into a job at a top 20 department is that they achieved this at the time of their first job—often with the aid of a postdoctoral fellowship from a prestigious department or an accompanying bachelor's or master's degree from an elite university" (p. 251). [This seems to be the only direct relevance to postdocs.]	Sample consists of sociologists. Postdocs are not the focus of the study. Data gathered from faculty in 1995, so they reflect earlier labor market conditions.

Author and date	Subjects	Data	Methods	Key findings	Limitations
Chang et al., 2005	Cancer Prevention Fellowship Program at the National Cancer Institute	Archival information, alumni placement records, administrative records	Case study framed around how the program addresses competing demands on mentors, working conditions, training for interdisciplinary, and career development support.	The program could be used as a model for other interdisciplinary fields, since university disciplinary departments don't provide this type of postdoc opportunity. Slightly over half of participants (55%) go on to take positions in government.	Single case study. May not generalize to university postdocs. Authors affiliated with the National Cancer Institute may not provide unbiased evaluation.
Corley and Sabharwal, 2007	7980 science & engineering academics who worked full-time at four year colleges or universities, medical schools or university research institutes.	2001 SDR	Chi square, t-tests, OLS	Foreign born more likely to be in postdoc positions and to have taken that position due to lack of other opportunities. Foreign born postdocs much less likely to have taken a postdoc to work with a specific person. Foreign-born postdocs less satisfied and more productive, except for patents.	Cross-sectional. Did not disaggregate foreign-born by country of origin. SDR data only include those with PhDs earned in U.S.
Curtis, 1969	10,740 postdocs. 4,040 departments at 357 schools. 2,195 faculty who mentor postdocs and 564 who don't. 125 universities. 20 campuses. Fellowship sponsors.	Surveys, interviews, campus visits.	Primarily descriptive	Census and description of U.S. postdocs.	Older data of primarily historical interest.
Davis, 2009	Includes 22,400 postdocs at 47	Survey	Correlations, robust regression with an	Postdocs benefited from structured oversight and professional development. Few benefits tied to compensation.	Cross-sectional. Limited causal inference. Underrepresenta

Author and date	Subjects	Data	Methods	Key findings	Limitations
	institutions		M-estimator, logistic regression, Poisson regression.	Writing research/ career plans at beginning of appointments associated with 25% productivity increase. Other beneficial activities: teaching, learning about non-academic careers, and training in proposal writing and project management.	tion of African-Americans and noncitizens among respondents.
Fox and Stephan, 2001	2348 doctoral students in 80 departments of chemistry, computer science, electrical engineering, microbiology, and physics, 1993-1994.	Mail survey by Fox, SDR.	Chi-square tests, cross tabulations	The wide availability of postdoctoral positions in microbiology may lead new PhDs in that discipline to view their career prospects more favorably than fields without those options, regardless of availability of tenure-track positions.	Data collected from doctoral students in 1993-1994 and 1993 SDR data from PhDs completed in 1987-1992. Lack of data on number of job candidates and openings.
Gaughan and Robin, 2004	400 French life science PhDs and 407 US life and physical scientists at URCs. French rec'd PhD 1984-1994 and US 1984-1997.	French data were from a survey and US data were coded from CVs (per Dietz et al. 2000).	Discrete time proportional hazards model.	Postdocs delayed entry into long-term academic employment in France, but not in the US, probably due to emphasis on early career mobility in the US. About 1/3 of each group took a postdoc. Note: French postdocs are almost by definition outside of France.	CVs do not provide data on non-academic career paths. Selection on dependent variable. Data reflect doctorates earned 1984-1997.
Helbing et al., 1998a	1,322 Postdoctoral fellows in life, physical, and social sciences.	43 Likert-type items from a mail survey.	Factor analysis and one-way ANOVA.	Satisfaction decreased and stress increased the longer someone was a postdoc. 60-70% reported being actively engaged in the search for a new job. Postdocs in Canada are typically not treated as employees.	Canadians, mostly in Canada and some in the U.S. Cross-sectional. Data collected in 1996.
Helbing et al., 1998b	Same as Helbing et al. 1998a.	Same as Helbing et al. 1998a.	Factor analysis and one-way ANOVA.	Women and men were similar in many ways. Women were more likely to be found in lecturer/ research associate roles or to name those as career goals. Women with children expressed stress primarily related to isolation and workload. Men with children expressed stress primarily in relation to finances.	Canadians, mostly in Canada and some in the U.S. Cross-sectional. Data collected in 1996. Emphasis on advocacy may compromise neutrality.

Author and date	Subjects	Data	Methods	Key findings	Limitations
Hornbostel et al., 2009	695 applicants for Emmy No ether fellowships. Particular focus on 294 applicants in physics and medicine, of whom 50 were selected for review.	Publications from Web of Science database and internet search via Google and MSN. Online survey. Interviews. Applicant files.	Content analysis, biblio metrics, descriptive statistics.	Reviewers were successful in selecting productive researchers. In medicine, there was little difference in outcomes between the selected and rejected applicants. In physics, the selected applicants had better placement and productivity outcomes.	Applies to a single prestigious fellowship in Germany. Focus on disciplines of physics and medicine. Prestige of coauthors may bias measures of publication productivity.
Horta, 2009	492 doctorate-holding faculty members at higher education institutions in Mexico	Data from 1999-2002 gathered in the survey by CONACYT and UNAM.	Written survey. Ordered probit negative binomial regression.	Postdoc was significantly associated with increased levels of all types of international information exchange.	Study focused on those who were faculty members in Mexico 1999-2002. Differences between younger and older faculty indicate that effects of postdoc appointments have changed over time and may not generalize to the present.
Lan, 2009	Chinese and Indian students earning S&E PhDs 1994-2000, ages 27-36, with 4-7 years doctoral study.	SED data.	Uses eligibility for the 1990 Chinese Student Protection Act (EO12711) as an instrument for having a permanent visa. Linear probability model, OLS and 2SLS. Probit model to estimate marginal	New PhDs from developing countries are more likely to take postdocs if they have temporary visas than if they have permanent ones. This effect is not found for PhDs from developed countries. The role of visa status is isolated through the use of CSPA as an instrument. This effect is most significant in fields where postdocs are not expected of most PhDs, such as chemistry and physics.	Although this is one of the stronger studies methodologically, Lan notes that it was not possible to differentiate between different types of permanent visas, which may bias estimates.

Author and date	Subjects	Data	Methods	Key findings	Limitations
			effects. Local Average Treatment Effects (LATE).		
Laudel and Glaser, 2008	16 Australian researchers, 9 of whom are in the sciences	Interview transcripts, bibliographic records, ISI, SCI	Secondary analysis. Creation of chronological career profile including publications, citations, research topics, job positions and their characteristics in terms of resources and autonomy.	Apprentices fade from community career by abandoning research or taking a role where they support research by others. All ECRs became independent researchers had built on the PhD topic.	In Australia. Universities were hiring those without research experience for faculty positions, unlikely in the U.S. Career profiles used were a methodological innovation, not an established approach. Some desirable information not available in secondary data. Only 9 subjects were in the sciences.
Libarkin and Finkelstein, 2001	28 Fellows (PhD scientists) and 11 mentors in the 3 cohorts of Postdoctoral Fellowships in Science, Mathematics, Engineering and Technology Education (PFSMETE), 1997-1999.	Open-ended survey questions from NSF (fellows only), Likert-scale program evaluation questions (Fellows and mentors), and open-ended topical questions (Fellows and mentors).	Thematic and quantitative descriptive content analyses	Most respondents were highly satisfied with the program. Consider implications of providing funding that is not through host institution (benefits, status, isolation) and challenges of participating in multiple disciplines.	Evaluates a specific NSF-funded fellowship program for scientists interested in science education research. Evaluators had also been program participants. Not enough time had passed to measure long-term outcomes.

Author and date	Subjects	Data	Methods	Key findings	Limitations
Martinez et al., 2007	1,322 postdoctoral fellows at NIH. 42.6% women.	A 48-question web survey that collected demographics, info on quality of postdoc experience (not presented in this article) and information on career transition decisions.	Chi-square tests	Women are less likely to seek a PI position and less likely to persist in seeking a PI position if they don't find one right away. Therefore, PIs are selected from a pool with fewer women. Women express a lot more concern about children and family relative to career planning. They also express less confidence in abilities and have few female role models.	Cross sectional. Respondents were intramural postdocs at NIH and may differ from academic postdocs.
McGinnis et al. 1981	557 biochemists who earned PhDs in late 50s early 60s	Archival, bibliometric	OLS, logit, multinomial logit	Predoctoral research productivity does not influence who does a postdoc or the postdoc's prestige. A postdoc does not seem to affect one's chances of getting a prestigious job, but the prestige of the postdoc has a major impact on the prestige of subsequent jobs. Postdoctoral training seems to result in substantial increases in later citation rates, but where the training occurred makes little difference in citation rates. The modest effect of postdoctoral training on publication rates disappears when employment sector is held constant.	Sample restricted to biochemists who earned doctorates in 1957, 58, 62, and 63. This study examined a period of plentiful academic jobs.
Melin 2004	284 Swedish PhDs who had a stay abroad as a junior guest researcher	Mail survey	Quantitative descriptive, Gini-coefficients	Swedes tended to do postdocs in countries that have been historically dominant in science rather than emerging. About half did postdocs in US. Networks played a role in finding postdoc, but supervisor was usually not directly involved. Collaborations often continued after the postdoc.	Swedish respondents had received grants 1984-1999. That is, all had Swedish government funding. Those who had left Sweden were not in the sample. Retrospective self-report data.

Author and date	Subjects	Data	Methods	Key findings	Limitations
Melin, 2005	Same data as Melin (2004) plus 15 telephone interviews.	Same data as Melin (2004) plus 15 telephone interviews.	Quantitative and qualitative description.	Negative consequences of postdocs were mainly related to reintegration back at the home institution and were somewhat greater for women than for men. This has negative institutional as well as personal effects.	Similar to Melin 2004. The fact that Swedish postdocs typically had a home institution to return to is very different from the U.S. model.
Meng and Su, 2009	388 scientists at R1 universities	CVs and survey responses from Research value mapping project. Prestige rankings.	Negative bionomial regression	Postdocs increase research productivity over first 3 years in PhD. This effect does not vary by gender. Women's production remains lower whether or not there is a postdocs.	Respondents were faculty members at R1 universities, so they were selected on a dependent variable. Significant truncation of information on CVs may bias sample.
Mishagina, 2009a	15,000 white men with PhDs in natural sciences and engineering	SDR 1973-2001	Transition model with independent competing risks.	Those who did many postdocs were more likely to leave S&E for good, but were no more likely to switch between R&D and applied work. The more time passes without getting an R&D position, the more likely the person is to leave science.	While this is one of the methodologically stronger studies, the data generally reflect a much earlier time period. In some analyses, only male scientists are included.
Mishagina, 2009b	Men and women in the life sciences. Comparison of trends in exit rates across disciplines.	SDR 1973-2001	Dynamic occupational choice model. Method of simulated moments.	Data seem most consistent with scientists seeking information about their level of research ability. Results are consistent with sorting based on comparative, not absolute, advantage. Not specifically about postdocs.	While this is one of the methodologically stronger studies, the data generally reflect a much earlier time period.

Author and date	Subjects	Data	Methods	Key findings	Limitations
Mishagina, 2009c	Doctorate recipients 1957-2005, not just scientists.	SED	Nested logit model, probit model for EU-15.	US doctorates became more likely to take a first position in Canada over time. U.S. citizens were more likely to move to Canada during the Vietnam war and Middle Eastern graduates were more likely to move to Canada after 9/11. High U.S. unemployment made U.S. and 3CNs more likely to go to Canada, but did not affect Canadians. (This essay was not really about postdocs, but was about first position after the doctorate).	While this is one of the methodologically stronger studies, the data generally reflect a much earlier time period.
Musselin, 2004	18 departments of history and mathematics in France and Germany	Observations	Field research	A European academic labor market is impeded by differences among national labor markets. Individual actors also make use of academic mobility in a way that does not lead to careers outside of the home country.	Focus is on France and Germany and disciplines of math and history. France and Germany may be somewhat unique in expecting instruction to take place in the local language. This paper summarizes findings from reports of research for the French government and does not describe methodology. The reports were completed in 1997 and 2002.
Nerad and Cerny, 1999	5,854 PhD graduates from 61 universities in biochemistry, computer science, electrical engineering, English, mathematics, political science, 1982-85.	Ph.D.s--Ten Years Later Survey	Crosstabulat-ions and descriptive statistics.	Biochem stayed longer in postdocs and had lowest % tenured faculty. Women were much more likely to take a postdoc because it worked for them and their spouse. Postdocs had a strong effect at moving male PhDs into tenure track and tenured positions.	Subjects obtained PhDs in 1982-85. This is a summary of a larger study and provides little methodological detail.

Author and date	Subjects	Data	Methods	Key findings	Limitations
Nolan et al., 2004	1,595 tenure track faculty at NRC top-50 chemistry departments	2001 ACS Directory of Graduate Research, WebCaspar	Description and crosstabulat-ion, Gottselig and Oeltjen "impact factor" for success of graduate placement.	Over 90% of new faculty had held a postdoc. Fellowships at top 5 supplier schools had strong beneficial effects on placement in top 50 programs. Women continued to face barriers to hiring in chemistry.	Subjects were chemistry faculty in top departments, half of whom had received doctorates before 1979.
Nolan et al., 2008	455 graduates (135 women) from 11 top chemistry departments, 1988-1992	Survey data	MANOVA	Women's responses indicated a lower perceived level of interest by their postdoc advisor in their research findings, research ideas, and publication opportunities. No difference was found in how men and women rated their post doc advising relative to others in their program or how they found their first career position.	Relied on retrospective self-reports of mentoring experiences. Subjects received PhDs in chemistry from top-10 departments in 1988–1992.
Puljak and Sharif, 2009	301 postdocs at the UT Southwestern Medical Center in 2005 at 150 research universities	Survey results	Harcopy survey, 37 questions	This is a heavily immigrant postdoc population. People stay in postdocs for a long time because faculty positions scarce. Most postdocs would like to stay in science. Priorities are job placement, salary, and training, which should lead institutions to focus on job and training opportunities.	Subjects located only at UT Southwestern Medical Center. Postdocs with strong opinions or interest in joining an association may have been more likely to respond. Postdocs on long assignments may have been oversampled.
Recotillet, 2007	1,744 French PhDs from 1996 in science, engineering and humanities.	Survey in 1999.	Treatment effect model, bivariate selection rule.	Postdocs function as a signal because the wage premium associated with them disappears when selection bias is controlled.	Subjects received doctorates in France in 1996. Does not distinguish among types of postdoctoral appointments.

Author and date	Subjects	Data	Methods	Key findings	Limitations
Reskin, 1976	450 doctoral chemists who earned degrees in US 1955-1961. 221 were female, 223 were a systematic random sample of males.	Directory of Graduate Research, American Men and Women in Science, other biographical sketches, and mailed questionnaires. Chemical Abstracts, Science Citation Index.	Analysis of covariance	For men, postdocs reflected predoctoral achievement and predicted future career advancement. These relationships did not hold for women, a finding most consistent with a sex discrimination explanation.	Subjects earned PhDs in chemistry 1955-1961. Postdocs were defined so as to only include prestigious fellowships.
Stephan & Ma, 2005	US PhD recipients in 10 broad fields of science & engineering who indicated they planned to stay in the US.	SED data, 1981-2000, SDR data for 1995, which contains additional career history questions, including up to 3 postdocs.	Logit analysis and duration model of log length of postdoc experience.	Graduates have become more likely to take postdocs and remain in postdocs for longer periods of time because a higher proportion of them are on temporary visas, a higher proportion of them are in the life sciences, and they have faced a more difficult job market. Human capital may be wasted because of age and tenure effects.	SED data span from 1981-2000. Labor market conditions measured subjectively.
Su, 2009a	Subsample of 514 scientists with adequate career data from 1647 responses and 1106 CVs from tenured or tenure track faculty in 13 S&E disciplines.	From Research Value Mapping project at GA Tech.	Questionnaire responses and coded CVs. Multinomial logit regression.	Did not support the idea that postdocs were less qualified than non postdocs. Postdocs in prestigious departments were associated with appointments in prestigious departments. Prestige of PhD department also had an effect. No evidence that pre-doctoral productivity mattered. At about 3 years, a postdoc shows its placement benefit Foreign postdocs are more likely to be placed in prestigious departments, except for Asians. No gender differences.	Subjects were faculty at R1 universities. Difficulty in determining which positions were postdocs from CV data. Absence of gender effect may be due to not including other demographics like marriage and children.

Author and date	Subjects	Data	Methods	Key findings	Limitations
Su, 2009b	Subsample of 860 scientists. 388 w/in 3 years of degree, 245 w/in 9 years of degree, and 227 w/in 13 years of degree	From Research Value Mapping project at GA Tech.	Questionnaire responses and coded CVs. Negative binomial regression.	Postdocs increase research productivity but only during first 3 years. Departmental prestige increases productivity but only in highly prestigious departments. In an example of cumulative advantage, postdocs increase future productivity by increasing the chances of being hired in a highly prestigious department.	Average year of PhD receipt was 1986. Subjects were faculty at R1 universities.
Subotnik and Arnold, 1995	11 women doctoral scientists identified as high potential in H.S. 4 were currently postdocs.	1-2 hour taped phone interviews	Grounded theory	Taxonomy of factors that influenced women's careers: professional advancement structures in science, the funding climate for scientific research, dual career constraints, commitment to social change, and maintenance of friendship and family ties. Career categories: facing in, peering out, open to opportunity, and focusing on balance. Of the 4 postdocs, 3 were classified as peering out.	Exploratory study included only 4 current postdocs.
Wei, Levin, and Sabik, 2009	3,255 postdocs in the U.S.	Sigma Xi survey conducted 2003-2005	Simple comparisons, OLS, Poisson, and probit regression, fixed effects	Foreign postdocs use more impersonal search methods, although they begin to use more personal methods over time. People who use personal search methods are more likely to be in their degree field. Those who stay in the same fields are more satisfied, implying that field switching is probably involuntary. Foreign postdocs have higher turnover. Personal search methods are also associated with increased productivity.	Subjects at top 20 universities and NIH. Difficulty categorizing subjects by personal or impersonal search method.
Zubieta, 2009	100 UK university researchers, recipients of Engineering and Physical Sciences Research Council project grant.	CVs coded to identify career transitions, ISI Web of Knowledge, patent data from the European Patent Office	Exploratory and descriptive.	There seem to be two common patterns of careers -- going straight to a job or going on a postdoc at another institution (often int'l) and returning to the doctoral institution. Using postdocs for mobility was more common in the pure sciences than in transfer sciences. Findings about the mechanism by which postdocs provide an advantage was ambiguous. Unlikely to generalize to the U.S.	Exploratory descriptive study. Sample were UK researchers with an average of 18.5 years of experience. Low response rate (15%). Unable to distinguish causal role of international postdoc

Author and date	Subjects	Data	Methods	Key findings	Limitations
	From 38 academic institutions in four scientific fields:				appointment on productivity and career.
Zumeta, 1984	Varied	SED, SDR, HERI Surveys of 3 groups.	Stepwise discriminant analysis, MANOVA	Growing share of postdocs was in distinguished departments. A lower proportion of postdocs received fellowships. Many more scientists are now using postdoc appointments to train in a field other than the PhD. Postdocs may now be spending slightly more time on paperwork than on research.	Describes postdoc experiences in '60s and '70s.
Zumeta, 1985	Varied	SED, SDR, 1976 Survey of Biomedical and Behavioral Scientists, HERI Surveys (1977)	Stepwise discriminant analysis, MANOVA	Quality of postdocs has declined in some key fields and this needs to be considered in evaluating outcomes. The lack of job opportunities for new PhDs has led to the increase in postdocs. Postdocs are becoming more common in the humanities/ social sciences, and there is little rationale or evidence for their effectiveness in that context. A postdoc does not appear to improve future earnings. Total career research productivity may increase as a result of a postdoc, but this may not be justified by value to the individual or society, especially in behavioral and social sciences. In natural sciences, society may benefit, but the individual may not.	Describes postdoc experiences in '60s and '70s.

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