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MOVING OUT OF ACADEMIC RESEARCH: WHY SCIENTISTS STOP DOING RESEARCH?

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Abstract

This study examines the determinants of exit from academic research which occurs when academic researchers move into positions in academe which concentrate on non-research activities such as teaching or administration, or when researchers leave academia and move into industry. Drawing on career data for 13,500 Japanese PhD graduates in hard sciences (all scientific fields except social sciences and humanities), we develop a set of econometric models to test the determinants of exit from a career in academic research. We find that academics' scientific productivity and academic network are negatively correlated with abandoning a university research career, and that female academics, and researchers in less-prestigious universities, tend to exit academic research more easily. Individual and institutional network effects play a role mainly for senior researchers. The results indicate also that the determinants of exit are contingent on scientific field and career stage.

Keywords

Researcher mobility; academic career; academic labor market; exit

1. Introduction

Academic research is extremely competitive, and its "up-or-out" nature inevitably results in a proportion of academics leaving a research career after initial involvement. Although this selection process is fundamental in explaining the highly skewed scientific production in academia (Lotka 1926), we know little about what characterizes exit from academic research. Most of the sociological and economic literature that analyzes science, concentrates on explaining success, and focuses on the performance of academic stars. However, if the selection mechanisms are imperfect, for example, if selection is driven by other criteria than merit, then the investment in human capital will be used inefficiently. Policy makers and scientific communities have expressed concern over these issues. Gender and ethnicity discrimination are examples of biased selection criteria. Wolfinger et al. (2009) indicate that female PhDs are disproportionately more likely to be employed as non-tenured faculty and to exit the paid labor force, even when controlling for academic productivity (Kaminski and Geisler 2012), while Ginther et al. (2011) show that US National Institute of Health (NIH) grants are less likely to be awarded to certain ethnicities. Such discrimination could exclude potential talent from continuing an academic research career after completion of the PhD, or expedite mobility out of an academic research career. There are other factors that also can discourage promising researchers from pursuing an academic research career after completion of their doctoral study. Donowitz et al. (2007) suggest that American physician-scientists tend to favor lucrative practitioner careers, and are discouraged by the unstable system of funding for junior researchers. In addition, the number of academic positions open to junior researchers in the US, EU, and Japan has failed to keep pace with the numbers of new doctoral graduates with the result that even the most capable are opting for non-academic research jobs (NISTEP 2009a; Stephan 2012).

The present study tries to shed more light on the process that induces academics to leave active research, by examining the determinants of academic research exit based on a sample of Japanese academics. We define “researcher exit” here as the case of an academic researcher abandoning research after some period either to take up an academic position that focuses on non-research activities such as teaching or administration, or to move into industry. There are several potential determinants of exit from an academic research career; we focus on individual, institutional, and geographical factors, drawing on the literature on academic mobility (e.g., Allison and Long 1990; Chan et al. 2002; Crespi et al. 2007, 2006), search theory models (e.g., Burdett 1978; Jovanovic 1979; Mortensen and Pissarides 1994), and policy research on academic career design (e.g., Gaughan and Robin 2004; Ginther and Kahn 2004; Long et al. 1993).

The prior empirical literature on academic careers is based mostly on the US and Europe. With the exception of some research on higher education (Arimoto 2011; Teichler et al. 2013; Yamanoi 2007), the Japanese academic labor market has been understudied. Our main aim in this chapter is to offer a comprehensive analysis of exit among Japanese academic researchers. We employ a sample of 13,500 PhD graduates in hard sciences (all scientific fields except social sciences and humanities), who obtained their doctoral degrees in the period 1985-1989; the data source is the Japanese National Library’s PhD degree database. We follow the careers of the sample graduates over 20 years (from 1990 to 2010) using the Japanese national research grant program, Grants-in-Aid (GiA) data.[1] Our econometric models suggest that the determinants of exit from an academic research career include scientific productivity and academic network which are negatively correlated with moving out of academic research, and that female researchers and researchers in less-prestigious universities have a higher probability of exiting from academic research. The findings suggest

[1] GiA is the primary national research funding system in Japan.

that the determinants of moving from academia are contingent on scientific field and career stage, and that the selection process in Japan is, at least partly, based on merit but may also be based on gender and university prestige, resulting in the unintended exit of potentially talented researchers.

2. Career path and exit from academic research career

In Japan and other advanced countries, the professional career of an academic researcher starts after completion of postgraduate-level education (e.g., PhD degree). Some doctoral graduates choose to pursue an academic career and continue to do research and teaching in academia, others focus mainly (or only) on teaching, and some choose research or non-research jobs in industry.

We consider the critical points in the academic research career path as those moments where the probability of leaving an academic research career is higher. Exit can be regarded as a type of mobility toward non-academic research employment, which may occur at various points in an academic research career. In some countries such as France and the UK, there are special PhD programs that allow students financed by companies to pursue more focused research projects that are aligned to the firms' interests. It is not surprising that most of these students continue their career in industry. If we exclude these cases, the three most important decision times are: (1) after PhD graduation, (2) at the time of consideration for a tenured/permanent position, and (3) after obtaining a permanent position. At these moments, academics might be tempted to leave the academic labor market as the result of a job offer in a company, or might decide to focus completely on teaching and/or administration and give up research activity. However, the probability of moving to a job in industry is small due to the specificities of the Japanese science market; e.g., in 2004 only 0.1% of academics moved from a job in a university to an industry job (METI 2006).[2] In what follows we discuss the three main moments when the risk of leaving an academic research career is higher, in the context of Japan.

In most OECD countries, students have completed their doctoral research by the time they reach their early 30s; the median age of graduation is 33 in the US, 31 in Switzerland, and 32 in Japan (Auriol 2010). Most PhD graduates who intend to pursue a career in academic research spend their first period after graduation in a temporary position such as a postdoc, before achieving their first assistant professor (or equivalent) position (Auriol et al. 2013). For example, in European countries such as Germany, the Netherlands, and Spain, the percentage of doctoral graduates on temporary contracts within the five years after graduation is around 40% (Auriol et al. 2013). In Japan, since 2005 doctoral graduates are awarded an assistant professor position after five or six years of postdoc employment on average, with only 15% of PhDs achieving this position immediately after graduation (Yamanoi 2007: Ch. 12). The postdoc period has been extending in most countries (Stephan 2012). For example, in the US in 2006, only 15% of biology PhDs were in tenure-track positions six years after graduation, compared to 55% in 1973 (Stephan 2012). This discouraging and risky career prospect can dissuade even excellent academics from pursuing an academic research career. Among a sample of about 4,000 PhD students in US Tier 1 research universities, Sauermann and Roach (2012) show that an academic research career is considered attractive by only about a third of respondents in life sciences and physics. Other careers such as academic teaching, civil service, employment in an established firm or a start-up are perceived as extremely attractive by a large share of PhDs students; e.g., 53% of chemistry PhDs considered a job in an established company as the most attractive career path.

A few studies have examined the determinants of career choice at this early stage. Gaughan

[2] See section 4 for information on the Japanese academic context.

and Robin (2004) use US and French data and suggest that the prestige of the undergraduate institution is associated with the likelihood of obtaining the first tenure-track position. Similarly, Debackere and Rappa (1995) show that the prestige of the graduate school for American neural network scientists is significantly correlated with the prestige of the first employer.

For those PhDs who survive the postdoc period and manage to secure an assistant professor position, the second critical point in the academic research career is the time at which the faculty member is considered for a tenured (permanent) position. In the US, tenure is usually awarded seven to nine years after initial hire (Stephan 2012). In other countries, the system is less structured and rolling or temporary contracts over periods of four to eight years are common. Failure to obtain tenure can often result in job mobility to a lower ranked university with more or only teaching duties, a move to a job in business, or exit from the market. A few studies have analyzed the probability of being awarded tenure. First, in a sample of biochemistry graduates from US universities, productivity measured by publication count is found to be positively associated with promotion from assistant to associate professor (with tenure), and to full professor (Long et al. 1993). Second, there is an important gender difference; several studies indicate that females are less likely to be given tenure, and have to wait longer for the offer of a permanent position (e.g., Ginther and Kahn 2004; Long et al. 1993). Wolfinger et al. (2009) examine the contract types of first employment and suggest that female PhDs in the US are less likely to obtain tenured positions and more likely to exit the labor force. Third, academic mobility across institutions has an influence. Although mobility can contribute to researchers' social capital and productivity, Long et al. (1993) and Cruz-Castro and Sanz-Menendez (2010) suggest that mobility delays promotion possibly because the 'tenure clock' is continually being reset.

Finally, academic researchers that have obtained a tenured position (associate professorship) may still choose to leave a research career to move to a job in a business organization or to refocus their academic profile towards a teaching and administrative position.

3. Determinants of Exit

This study examines exit from academic research drawing on search theory in labor economics (Burdett 1978; Jovanovic 1979; Mortensen and Pissarides 1994). Exiting from an academic research career depends on the probability of receiving an offer (and accepting it) to pursue a career in academic research compared to academic teaching, administration or industry. We identify individual, institutional, and geographical factors correlated to persistence in an academic research job.

3.1. Individual Factor

3.1.1. Scientific productivity

The productivity of academics should affect their value in the labor market. Research organizations try to retain productive employees, and to dismiss less productive employees (Becker 1962). Highly productive academics have greater chances of both employment in a prestigious university (Allison and Long 1987), and of promotion (Long et al. 1993). These studies suggest consistently that the opportunity for a job in academic research should be higher for more productive academics who consequently have a lower probability of leaving an academic career (Brewer 1996). In parallel with their research responsibilities, academics usually engage in non-research activities such as teaching and administration. Some academics choose (or are forced) to concentrate on non-research jobs in academia and to give up their researcher careers. The expertise required for teaching, administration, and research may coincide to a degree, so productive researchers could become productive teachers or good administrators. This raises the question of whether higher research productivity leads to a higher chance of a teaching or administration job offer. In relation to social status, salary, etc., academics seem to gain higher utility from a research job than from pure teaching or administration responsibilities.[3] Thus, we hypothesize that productive researchers are unlikely to become teachers or administrators, and have a low probability of exit. However, we recognize that there are also a few cases in which extremely productive researchers become excellent administrators.[4]

In some scientific fields where science and technology overlap such as transfer and Pasteur-quadrant sciences (e.g. biomedical, software engineering), academic research expertise can be relevant for industry research. Thus, productive academics may attract job offers from business (Lazear 1984; Murnane et al. 1991). Stern (2004) and Sauermann and Roach (2014) suggest that scientists may choose industry jobs if the accompanying higher salaries compensate sufficiently for loss of freedom to do the research they like and to publish. Zucker et al. (2002) show that productive (measured by citations to their publications) academics are more likely to move to an industry job in the US biotech field. Thus, if the requirements for the industry job are academic research expertise, the effect of scientific productivity on exit could be positive.

[3] Top executive administrative positions (e.g., provost, dean) may be both prestigious and lucrative. Researchers who leave research for such senior positions are regarded as examples of voluntary exit from academic research. However, the number of these job opportunities is limited. In Japan, executive administrators are often appointed from among professors within the university with some rotation pattern.
[4] See, for example, the case of David Baltimore Nobel laureate and president of the California Institute of Technology (Caltech) from 1997 to 2006.

3.1.2. Funding inputs

Academics need research funding in order to undertake research. In many countries, non-competitive block grants have been replaced by competitive funds. Since academics' capacity to raise competitive funding is correlated with their productivity (Dasgupta and David 1994), we would expect the availability of competitive funds to be negatively correlated with the probability of exit since this type of funding is a research input. Even controlling for scientific productivity, stable funding could have a mitigating effect on exit. Academic research in the natural sciences in particular, is heavily dependent on large research funding support for laboratory costs and the salaries of PhDs and postdocs. Thus, securing funding is a major concern for laboratory heads (Shibayama et al. 2014; Stephan 2012). Secure funding should ensure a continuing research career (Donowitz et al. 2007; Zerhouni 2006) and increase its expected utility, thereby reducing potential exit. Thus, we expect that competitive funding inputs are negatively associated with the likelihood of exit.

3.1.3. Gender

It is well-known that women are underrepresented in academia. For example, Auriol et al. (2013) show that less than 40% of PhD graduates in most OECD countries are female. In Japan, the gender imbalance is particularly pronounced[5] with women accounting for only 26% of all PhD graduates in 2006 (NISTEP 2009a). Female researchers are more likely to have child rearing and domestic responsibilities which are likely to cause earlier exit. Female researchers are less likely to obtain tenure, and to take longer to achieve it (Ginther and Kahn 2004; Long et al. 1993; Wolfinger et al. 2009). For example, although the situation has

[5] Japan, ranked 21st in the UN's gender inequality index, lags behind most OECD countries for improving the gender gap, (http://hdr.undp.org/en/statistics/gii).

improved over recent decades, in 2010 in the US, females accounted for 44%, 37% and 22% respectively of assistant, associate and full professor positions, (National Science Board 2014: Ch.5). The statistics for Japan show that, in the natural sciences, only 15.7% of assistant professors are female and a mere 3.8% achieve the position of full professor (NISTEP 2009b: 2-16). Based on these findings, we expect that females are more likely than males to exit an academic research career.

3.1.4. Academic career

Search theory shows that length of employment in the same organization stabilizes relations between employee and employer, and reduces job quit (Farber 1994; Jovanovic 1979). In the academic context, Crespi et al. (2007) show that the longer the academic remains in one university, the less likely he/she will move from academia to industry. This would seem to support the negative relationship between tenure and exit. However, it is plausible also that academic institutions appoint researchers with long tenure but diminished research excellence, to non-research positions. Thus, tenure could be correlated either positively or negatively with exit.

Job rank (assistant, associate, full professor, etc.) should also affect exit. Promotion is usually associated with research performance; greater seniority equates with greater propensity to do research. In addition, seniority brings greater job security and a higher salary, resulting in greater expected utility from an academic research career. Overall, we expect that job rank is negatively associated with the likelihood of exit.

3.1.5. Academic network

When academics are well embedded in a scientific community and have good connections with other academics, they are kept apprised of job vacancies. Zucker et al. (2002) show that the academic's external network, measured by the proportion of co-authors from different institutions, leads to mobility from academia to industry. Also, Crespi et al. (2007) indicate that network, measured by collaboration with external organizations, facilitates mobility from universities to public research organizations (PROs). Applying this evidence to the academic network, one can expect that researchers with good individual academic network connections will also be better informed about academic research job opportunities which consequently will reduce the likelihood of exit. This may be particularly true in the Japanese context where human relationships (connections) play an important role in the recruitment of academics (Yamanoi 2007).

3.2. Institutional Factor

3.2.1. Research organization

An institutional factor that is known to influence academic career is organizational prestige. Undergraduate or graduate study at a prestigious organization is found to be a good predictor of future academic employment (Gaughan and Robin 2004) and promotion (Long et al. 1993). In addition, it has been suggested that prior experience in an excellent organization leads to future employment in a prestigious organization (Allison and Long 1987; Debackere and Rappa 1995). These studies imply that organizational prestige should increase job offers for academic researchers and lead to higher expected utility, lowering the likelihood of exit.

Prestige is a complex concept that encompasses several factors. First, prestige is associated with the availability of resources for research. In general, prestigious organizations have more and larger sources of revenue, can invest more generously in research, and can maintain better facilities for individual researchers to conduct state-of-the-art research. This should increase the expected utility of an academic research career. A second factor is the institutional academic network. Prestigious organizations can employ excellent researchers and attract excellent external collaborators. This provides individual academics with advantages in the form of opportunities for intellectual interactions with peers, and access to their social capital. Thus, we expect that institutional capital, measured as funding input and institutional academic network (peer effects and social capital), will be negatively correlated with exit.

3.2.2. Scientific fields

In the context of academic research, individual academics have an affiliation to their particular university, and become deeply embedded in their respective scientific fields. Thus, their career paths should be affected by the characteristics of their field. These include academia-industry linkages which can increase job offers from industry, and are particularly important in Pasteur-quadrant sciences (compared to pure basic science) (Stokes 1997), where mobility between academia and business involves lower transaction costs and is more common, resulting in higher levels of exit. Field growth is another factor; in expanding fields, employment is more likely to increase and the enhanced job prospects should improve the expected utility of an academic research career. Therefore, the probability of exit will be higher in Pasteur-quadrant scientific fields, and field growth will be negatively associated with exit.

3.3 Geographical/labor market factors

In general, a career change involves a different work place. A geographical change incurs search and moving costs, so job vacancies in the same geographical vicinity should be associated with a higher likelihood of a job change. Disentangling types of employers, Zucker et al. (2002) show that mobility from academia to industry is positively associated with the number of biotech firms, and negatively associated with the number of top-rated universities in the area. The effect of concentration of universities is unclear because universities offer both research and teaching jobs. In an attempt to disentangle these two types of employment opportunities, we expect that the local concentration of research-intensive universities will be negatively correlated with exit, while local concentration of teaching-oriented universities will be positively correlated with exit. We control also for the size of the local labor market and supply of qualified researchers.

4. Context of Japanese Academia

Japan has three types of universities - national, regional (i.e., city and prefectural), and private universities - which offer four-year degree courses and postgraduate education. In 1985 (our sample is composed of academics who obtained a PhD degree in 1985-1989), Japan had 95 national, 34 regional, and 331 private universities,[6] with national universities focused on academic research, and most private universities focused on teaching. In 1985, 73% of undergraduate students were enrolled in private universities, and 24% in national universities, while 38% of graduate students were enrolled in private or regional universities, and 62% in national universities. In terms of research funding, in 1985, national universities

[6] School Survey conducted by the Ministry of Education, Culture, Sports, Science and Technology (MEXT; http://www.e-stat.go.jp/).

received 77% (decreased to 67% in 2010) of the total GiA budget, the primary national research funding system in Japan. Among national universities, the seven pre-imperial universities (Tokyo, Kyoto, Osaka, Tohoku, Hokkaido, Kyushu, and Nagoya) are considered exceptionally prestigious for both research and education. Academic research is also conducted in PROs (e.g., RIKEN).[7] In 2004, PROs employed approximately 10% of researchers, and universities 90% (METI 2006: 264).

Japanese universities have a three-level promotion system from the entry position of assistant professor or lecturer, to associate professor, and finally full professor.[8] Currently, before being appointed to an entry position, academics - especially in natural sciences – must spend a few years as a postdoc. In 2005, the average postdoc period was five or six years (Yamanoi 2007: Ch.12). In the 1980s, postdocs were less common, and young academics were often appointed as assistants or lecturers directly after graduation. According to a national survey of natural scientists (NISTEP 2009b), among respondents aged 26-36 years in 1990 23.5% had held a postdoc position, 70.5% had not. Among the former, approximately 80% spent three years or less as a postdoc.

Japan's academic system has a few relevant features. First, it used to be characterized by lifetime employment (Shimbori 1981; Takahashi and Takahashi 2009). Until a series of reforms in the 2000s allowed temporary employment, entry positions were mostly permanent (Watanabe 2011). Second, many Japanese universities operate a hierarchical "chair" system (Yamanoi 2007). The system consisted, and sometimes still is, of a full professor (the "chair"), responsible for a small team of junior researchers in entry positions and perhaps an associate professor.. Thus, while junior researchers in entry positions were cleared of unemployment risk, they had to (and have to) compete to be promoted and win a position of

[7] http://www.riken.jp/en/
[8] The position of assistant professor was officially introduced in Japanese universities in 2007. Previous to this, the position was designated "assistant" (Watanabe 2011).

an independent researcher. Third, Japan's employment practice is characterized by high rigidity and very low cross-sectoral mobility. According to a government statistic (METI 2006: 264) in 2004, only 1.1% of researchers (8,800 out of 790,900) moved across the three sectors of industry, government, and academia. In the same year, 97.4% of 291,100 university researchers were not mobile, 2.3% moved between two universities, 0.11% moved to industry, and 0.15% moved to government (i.e., PROs). Thus, industry is a less frequent destination for academics who leave university employment and, in Japan, exit is more likely due to academics giving up research and remaining in academia in a teaching or administrative position.

5. Data Description and Variable Measurement

5.1. Sample and Data

Our sample is composed of a cohort of 13,492 PhD graduates who were awarded a PhD degree in hard science (all scientific fields except social sciences and humanities) in the period 1985-1989.[9] We focus on the 1985-1989 cohort because a reform to the funding system allowed significantly more junior researchers to obtain grants since the mid 1980s (the number of junior grantees in 1980-1984 is about half the number in 1985-1989). This allows us to trace academic careers more precisely for up to 20 years. The data on PhD graduates were obtained from the Japanese National Library database[10] which provides full

[9] We exclude social sciences and the humanities because our theoretical framework to explain exit from academic research does not apply to these fields. PhD graduates from these fields account for 3.2%. We also exclude foreign-born graduates because name matching (explained later) for foreigners is difficult for non-unique notations of foreign names in Japanese characters, and because non-native Japanese graduates are unlikely to pursue an academic career in Japan (Franzoni et al. 2012). Foreign-students account for 7.3% of all PhD graduates. Finally, we do not include so-called paper-based PhDs who are awarded the degree on the basis of their research output (often based on corporate research experience) with no course work requirement; paper-based degrees are usually awarded to senior researchers and their inclusion would bias the analysis.

[10] Universities are obliged to archive all PhD dissertations in the National Library. The library creates electronic data upon receiving dissertations. There is open access to the database (http://opac.ndl.go.jp/).

names, degree field, year of degree award, etc.

To trace careers and identify exit from an academic research career, we exploit the GiA program database. The GiA program is the largest source of funding for academic research in Japan and covers all scientific fields and all ranks of researchers.[11] A survey of GiA grantees in 2006 indicates that only 3% of academic researchers depended for the majority of their research budget on funding sources other than GiA, and that this rate differs between fields with a maximum of 13% in engineering (Iida 2007: Ch.6).[12] Thus, we can reasonably assume that researchers who have never received GiA funding, or have not continued to receive it, most likely stopped doing academic research.[13] For each grant award, the database provides full names of grantees, grant size, affiliations, collaborators, associated publications after completion of the grant, fields of research, etc.

We created two datasets; the first includes cross-sectional information for the whole 13,492 PhD graduates, and the second includes information on 5,613 GiA grantees for the period 1990-2010. We linked the two databases on the basis of full names of PhD graduates and GiA grantees and found 5,613 matches among the 13,492 PhD graduates.[14] We consider that unmatched PhD graduates who never received GiA funding, exited before embarking on a professional academic research career (*pre-employment exit*).

We built an unbalanced panel that consists of the matched 5,613 PhD graduates who have

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[11] General information on GiA can be accessed from the MEXT website (http://www.mext.go.jp/a_menu/shinkou/hojyo/main5_a5.htm). Kneller (2010) and Asonuma (2002) provide overviews of the GiA and the general budgetary structure in Japanese universities. The GiA database provides information on all grants awarded under the system since 1965, covering 210,000 university researchers.

[12] Among the top 7 national universities, about 84% of full and associate professors had received GiA funding at least once in the period 2001-2005 (Shibayama 2011). Our exit measure might be less reliable for researchers in private universities, where dependence on GiA is lower.

[13] GiA grants are also awarded to researchers in PROs. Since PRO researchers are less dependent on competitive funding, our data might miss very active researchers in PROs and overstate exit. However, we believe that this effect is limited because of the higher mobility from PROs to universities (10%) and much lower mobility from universities to PROs (0.1%) (METI 2006: 264).

[14] Name ambiguity is not a serious problem since full names in Chinese characters are available in both databases. For some common names, we differentiate by year of graduation, and funding and scientific field.

received GiA funding at least once, and trace their career until exit or up to 2010. We consider that an academic who appeared in the GiA database but then disappeared has exited from an academic research career after a spell of academic employment (*post-employment exit*). Although the two original databases do not provide information on age, we can assume that PhD degrees were awarded at around 26-31 years of age (NISTEP 2009a). Since the retirement age in most universities in Japan was 60 (although this has now been extended), it is unlikely that researchers that exited our sample after having started an academic research career would be retired since they should be around 57 years old in 2010.

5.2. Dependent Variables

For pre-employment exit, we prepared a dummy variable that takes the value zero if a PhD graduate is matched with the funding database and 1 otherwise. The matching rate is 42%, and thus, the rate of pre-employment exit is 58%.

For post-employment exit, we prepared a dummy variable that is coded 1 for the last year the academic received a grant from GiA, and zero otherwise. We used the year 2010 version of the GiA database, and regard academics whose latest record in the database occurred in 2006 or later, as survivors, on the assumption that research-active academics are funded at least once in five years.[15]

5.3. Independent Variables

We prepared several independent variables for the individual, institutional, and geographical factors discussed above, drawing on the funding database and other public data sources. To

[15] Most funding is for 3-5 year periods.

analyze pre-employment exit, we took year of PhD graduation as the measurement year.

For individual level measures we include eight variables. The funding database provides the number of publications resulting from each funded project. By dividing this publication count by the number of project members and project duration, we can compute a yearly publication count for each academic. Since publication count can differ by field and year, we standardized this measure by field/year mean and standard deviation. We then compute the accumulated count of publications prior to each year (*pub stock*). We divide funding amount for each project by the number of project members and project duration, and summed them for each year, for each academic, to compute a yearly funding input. We standardize this by the field/year mean and standard deviation to compute stock value (*fund stock*). We code a dummy variable (*female*) 1 for female and zero for male. For academic career, we compute the number of years of employment each academic had in a university (*job tenure*). For academic rank, we constructed two dummy variables: the variable *full prof* takes the value 1 for full professor, and the variable *associate prof* takes the value 1 for associate professor. For academic network, we count the cumulative number of co-grantees related to a researcher's GiA funding (*#cograntee*) and we also control for the number of universities to which a researcher was affiliated (*mobility*).

We constructed four variables for institutional factors. The top seven national universities in Japan are regarded as prestigious research-intensive universities. To measure organizational prestige, we include a dummy variable that scores 1 for the top seven universities, and zero otherwise (*top7*). University-level funding input is computed as follows. We first compute the GiA funds for each intersection of university, field, and year, and then total funds for each field/year. We divide the former by the latter to calculate the proportion of funding distributed to each university (*%univ fund*). To measure the importance of the institutional academic network of the grantee university (as a proxy for peer effects and social capital), we count the number of researchers awarded GiA funding in each year in the same university and the same field (*#researcher*). To estimate field growth, we count the number of grantees in each year and each field, and calculate the annual growth rate (*field growth*).

Finally, for geographic factors, we constructed four variables at the level of the 47 prefectures. We collected the number of jobs in national universities located in each prefecture as a proxy for academic research jobs (*#national university employment*), and the number of jobs in private universities as a proxy for teaching-oriented job opportunities (*#private university employment*).[16] This is based on the assumption that national universities tend to be research-intensive and private universities tend to be teaching-oriented. We also collected employment numbers for each prefecture as a measure of employment opportunities in the private sector (*#industrial employment*).[17] Finally, we take number of PhD graduates in universities in the same prefecture to measure the labor supply (*#PhD graduate*).

6. Econometric Model and Results

The structure of our data allows us to analyze exit at a few distinct moments: (1) immediately after PhD graduation (pre-employment exit), (2) after the academic embarks on a professional researcher career (post-employment exit), divided into (2a) before achieving a tenured position, i.e., assistant professor (pre-tenure exit), and (2b) after achieving tenure, i.e., associate or full professor (post-tenure exit).[18] Section 6.1 presents the estimations for exit at moment (1) drawing on cross-sectional data for 13,492 PhD graduates, and estimates

[16] Source: School Survey conducted by the MEXT (http://www.mext.go.jp/b_menu/toukei/chousa01/kihon/1267995.htm).

[17] Labor Survey conducted by the Ministry of Internal Affairs and Communications (http://www.stat.go.jp/data/roudou/index.htm). Since data are available from 1997, data for the years 1985-1996 are imputed from year 1997. Employment numbers have been stable since the late 1990s.

[18] As discussed above, assistant professor positions were mostly permanent in the past. Thus, in our empirical setting, tenured position has the meaning of being granted the promotion to associate professor, academic rank that is usually associated to a tenured position in the US.

the likelihood of pre-employment exit by logit regressions.

In sections 6.2 and 6.3 we examine exit at moments (2a) and (2b). We use panel data for the whole careers of the 5,613 PhD graduates who received GiA funding at least once. We estimate the likelihood of post-employment exit by survival analysis, drawing on a duration model that allows us to analyze a point event (referred to as a failure event) which occurs after a certain period of time (spell length). The average spell length is 14 years. We draw on a discrete approach based on the complementary log-log (*cloglog*) model.[19] Based on Prentice and Gloeckler (1978), the discrete hazard time for individual i in time interval t to exit is estimated by the following function:

$$h_{it} = 1 - exp\{- exp(\beta X_i + \theta(t))\}$$

where h_{it} is the hazard rate and $\theta(t)$ is the baseline hazard function with spell duration (Jenkins 1995). A set of time dummy variables is included to capture the unobserved time-varying effect on the likelihood of exit.

6.1. Pre-employment Exit

We first examine *pre-employment exit* defined by no award of GiA funding. Table 1 presents basic information on exit by field, university, and gender. Table 1A provides a breakdown by PhD degree field: Medicine (48.2%), Engineering (16.1%), Science (15.4%), Dentistry (10.4%), Agriculture (6.2%), and Pharmacy (3.8%). Exit rates differ substantially by field. PhDs in Science, the most basic field, show the lowest exit rate (42.3%), or the highest rate of survival in an academic research career. Three medical fields (Medicine, Dentistry, Pharmacy) show high exit rates (> 60%), probably because of substantial demand for their

[19] A continuous approach can be employed. A Cox (1972) semi-parametric model yields a similar pattern of results.

labor in practitioner jobs (doctors, dentists, pharmacists, etc.). Engineering and Agriculture show medium exit rates (~52%) perhaps due to employment in industry.

Table 1B provides a breakdown by PhD awarding university. During 1985-1989, 142 universities awarded at least one PhD degree in hard sciences. The top seven universities accounted for 37.9% of PhDs, and their exit rates are somewhat lower (< 50%). Lower-ranked universities show higher exit rates, implying that more academic research jobs are given to graduates from top universities.

Table 1C provides a breakdown by gender and field. The proportion of females in all PhD graduates is 7.8%. In all fields, exit rates are higher for females (71.3%) than males (57.0%). The gender difference is greatest in Science (1.44 times more for females than males) and least in Pharmacy (1.09 times). The three fields with the highest exit rates for female scientists are Medicine (77%), Dentistry (73%), and Pharmacy (72%).

Table 2 shows the regression results. We regress pre-employment exit using a logit regression model. Appendix 1A provides descriptive statistics and correlations for the variables. Model 1 suggests that females are significantly more likely to exit before employment. This effect remains strong after introducing other factors in Models 2 and 3.

Model 2 includes institutional factors, and suggests two determinants of exit. Affiliation during PhD training has a significant effect; graduates from top universities are less likely to exit which is consistent with our hypothesis and summary data. Moreover, the number of researchers who received a GiA grant in the same university and field, proxy for institutional academic network, decreases the likelihood of exit. This may be because they help PhD graduates find employment through their large research network or because research active departments have greater capacity to employ PhD graduates on a temporary basis. University-level funding shows no additional effect on exit.

Field dummies are collectively significant. The field of Science shows the lowest exit propensity while Pharmacy, Medicine, and Dentistry show the highest propensity. This result is mostly consistent with our hypothesis. Since career structure might differ with scientific field, we ran the same set of regressions separately for each field. The statistical significance varies across fields but the sign of the correlation is consistent with the aggregate results except in the case of university-level funding which is negatively correlated with the probability of exit in Dentistry, and surprisingly, is positively correlated with the probability of exit in Engineering (see Appendix 2A for summary results).

Model 3 also includes geographical factors. Employment in research-intensive national universities has a negative effect, suggesting that the availability of academic research jobs in the vicinity reduces the likelihood of exit, as hypothesized. In contrast, and as expected, employment in teaching-oriented private universities, increases the likelihood of exit (move to a teaching oriented job). Employment in industry does not have a significant effect. Finally, a large number of graduates from the same geographical area facilitates exit perhaps due to over-supply and competition for research jobs.

6.2. Post-employment Exit

For academics who do not exit immediately after graduation (i.e. awarded funding at least once), we compute survivor functions (Figure 1). Figure 1A illustrates the function for the whole sample, indicating that academic exit was steady, with 40% persisting after 20 years in research. Job ranks at the time of exit, or final position of survivors is full professor (32%), associate professor (23%), and assistants or lecturer (45%).

We compute survivor functions for a few sample subsets. Figure 1B highlights field differences based on funding fields.[20] Funding fields consist of Clinical Medicine (30.3%), Engineering (17.0%), Mathematics and Physics (12.0%), Dentistry (10.1%), Biology (8.6%), Agriculture (7.0%), Chemistry (4.9%), and Pharmacy (2.1%). The survivor function shows particularly rapid exit in Clinical Medicine and Dentistry followed by Pharmacy. The other fields follow a similar trend with about 60% remaining after 20 years. In terms of PhD affiliation, the top seven universities account for 49% of those PhD graduates who remain in academic research. Graduates from these universities are significantly less likely to leave than those from other universities (Figure 1C). Finally, females, who account for 5.3% of those PhD graduates who remain in academic research, are more likely to exit than males (Figure 1D).

Table 3 shows the regression results for post-employment exit. Appendix 1A provides descriptive statistics and correlations for the variables. Model 1 includes only individual-level factors. Publication stock has a significantly negative coefficient, suggesting that high performers tend to continue in academic research. This effect is consistent after controlling for other factors in Models 2 and 3. Funding input has a negative coefficient, implying that larger yearly research funding for individual academics facilitates long-term engagement in academic research. Though Model 1 shows a negative sign for female, when we control for institutional and geographical factors (Models 2 and 3), in Model 3 the sign turns positive and significant, suggesting that females are more likely to leave academic research. Job tenure has a negative effect on mobility; i.e., academics who stay for longer in the same university are less likely to exit. However, this effect turns weakly positive when we control for geographical factors (Model 3), indicating that once we control for labor market characteristics, staying longer at the same university might be associated more with non-

[20] For those academics who did not exit immediately after graduation, we distinguish fields in slightly more detail drawing on the GiA database. Medicine is split into Basic Medicine and Clinical Medicine; Science is split into Biology, Chemistry, Mathematics, and Physics.

research jobs. Seniority reduces the likelihood of exit; i.e., assistant professors are more likely to exit than associate professors, and associate professors are more likely to exit than full professors, which is in line with our hypothesis. For the individual network effect, the number of co-grantees shows significantly positive coefficients (Models 2 and 3), which is contrary to our expectation that a larger academic network helps job search. This result is discussed further in section 6.3. Finally, previous mobility has a negative coefficient, suggesting that mobile academics tend to remain in academic research for longer. However, this effect decreases when we control for institutional factors (Model 2) which is explained largely by the field dummies, and becomes significant and positive in Model 3 when we control also for geographical factors. One interpretation of this result is that mobility might be forced rather than voluntary, and that lower performers who are less likely to be granted tenured positions need to move to lower ranked institutions to obtain more secure and teaching-oriented job.

In relation to institutional factors, our results suggest that academics in prestigious universities (*top7*) tend to stay longer in academic research which supports our hypothesis. The coefficient of number of researchers in the same university and same field is significantly negative, showing a decreasing likelihood of exit and confirming the presence of an institutional peer and social capital effect.[21] As for funding input at the university level, we find a small positive correlation with exit, contrary to our hypothesis, which largely disappears in Model 3. After controlling for social capital and peer effects (*#researcher*) and organizational prestige (*top7*), resource input has only a limited impact on the likelihood of exit.

[21] The number of researchers may be confounded by the size factor, since we control for the proportion of funding distributed to the university (%univ fund), we can interpret the number of researchers in the field in the university as a proxy for social capital and peer effect. We also ran the regression using amount rather than percentage of university-level funding and obtained qualitatively similar results.

Among field-related factors, Model 2 shows that field growth has a significantly negative coefficient. This suggests that in expanding fields, exit is less frequent, although when we control for geographic/labor market characteristics (Model 3), the effect becomes negligible. The field dummies collectively are significant. Among the nine fields, for post-employment exit we observe a relatively low propensity in Pharmacy, Biology, and Chemistry, and high propensity in Agriculture, Clinical Medicine, and Dentistry. We examined field difference by running the regressions separately for each field (see Appendix 2B for summary results).

Model 3 includes geographical factors. We observe a negative coefficient of number of jobs in national universities, suggesting that a higher number of researcher positions facilitates an academic career. We observe a positive coefficient of number of jobs in private universities, suggesting that the higher the number of teaching positions, the shorter the time taken for academics to leave academic research and accept a job in a teaching university. Model 3 indicates also that more PhD graduates from the same geographical area increase the likelihood of exit, suggesting the effect of oversupply. Finally, the number of jobs in industry has a negative coefficient. This effect is particularly strong for Biology and Basic Medicine (see Appendix 2B), maybe indicating that the presence of a proximate sizable industry sector increases the chances of industry funding allowing researchers to continue doing research.

Figure 2 depicts the estimated baseline hazard functions according to the predictions in Model 3, Table 3, for the set of PhD graduates who received GiA funding at least once. To draw the graphs, we average the predictions of the dependent variables for each subgroup. The *cloglog* models include dummy variables for each time period (year), which collectively are strongly significant. Figure 2A indicates that the probability of exit is initially relatively high, then it decreases, and after about 10 years starts to increase. By the end of the period the probability of exit is similar to the initial level. The early peak represents researchers who are trying to develop an academic research career - probably during their postdoctoral or assistant professorship period - prior to obtaining a tenured position. The later increase in the hazard rate would seem to correspond to academics leaving research and moving to non-research jobs.

Figure 2B compares initial affiliations and shows that the likelihood of exit from academic research is lower throughout the whole career, for academics who graduated from a prestigious university. Figure 2C compares gender effects, and shows a much higher exit probability in the early and later career stages for females.

6.3. Career-Stage Differences

Table 4 compares two career stages - before obtaining a tenured position, i.e., assistant professor (Model 1), and after achieving a tenured position, i.e. associate and full professor (Model 2). Scientific productivity is found to decrease the probability of exit in both stages. Funding stock, as expected, has a negative effect in the most senior stage. It also has a weak (and positive) effect in the junior stage, perhaps because many junior academics are supported financially by their supervisors, and obtaining their own funding plays a less important role. We find that females are more likely to exit during the junior stage but if they obtain a tenured position, their likelihood of exit is not significantly different from that of males (Takahashi and Takahashi 2010, 2009). Job tenure shows a positive effect in the senior stage, implying that academics might be assigned non-research jobs after very long employment. Mobility has a strongly positive effect in the junior stage but no effect in the senior stage. As discussed above, the observed mobility might be largely forced and associated with low performance.[22] Having obtained a tenured position, past mobility might not matter. The number of co-grantees is positively correlated to exit in the early career phase

[22] Mobility and performance are negatively correlated during the junior stage.

and negatively correlated to exit after obtaining tenure, indicating that the individual academic network exerts a moderating impact on exit only when the researcher has achieved a senior position and a well developed, consolidated academic network.

Among institutional factors, university prestige is influential only during the junior stage, suggesting that tenure is more often awarded to graduates from top universities who may be benefiting from institutional prestige. The number of researchers in the same university decreases the likelihood of exit only at senior levels, once again indicating that positive network effects are relevant only for senior academics. Geographic/labor market control factors have a similar effect in both stages although the number of jobs in private universities is significantly correlated only with exit by assistant professors, indicating that the choice to take up a career in a more teaching oriented university is usually made at an early stage.

7. Conclusions

This chapter has examined the individual level determinants of exit from an academic research career, controlling for institutional and geographic/labor market influencing factors, informed by the literature on academic mobility and academic careers (e.g., Allison and Long 1990; Crespi et al. 2006), and search theory in labor economics (e.g., Mortensen and Pissarides 1994). The up-or-out nature of an academic research career results in some academic researchers being forced to abandon an academic research career despite huge investments such as fellowships and supervisory support. This career selection process might be compromised by biased selection criteria, or a badly designed academic system, leading to unintended exit. Although this is a practical concern (e.g., Cyranoski et al. 2011; Donowitz et al. 2007; Ginther et al. 2011), few studies have examined exit from academia. The study described in this chapter is an attempt to fill this gap, based on a sample of Japanese academics in hard sciences.

The results confirm that productive academics are more likely to continue to do research, suggesting that the selection process is based at least partly on merit which is in line with the literature on academic careers (Allison and Long 1987; Becker 1962; Long et al. 1993). From a search theory perspective, the opposite effect is also plausible - that productive researchers attract offers of industry jobs or non-research jobs in academia; however, the results support this argument only for the field of Dentistry. Thus, scientific productivity increases job opportunities in academic research significantly more than other jobs. Coupled with the very low mobility from academia to industry in Japan (METI 2006), this result might suggest that the demand for labor from industry is not being adequately addressed by the academic system.

We also examined the impact of individual level funding and found that funding decreases the likelihood of exit only after researchers have obtained a tenured position, indicating that individual fund-raising capacity plays a role only if the researcher becomes a head of laboratory. With regard to discrimination in the selection process, our results show that females are more likely to exit an academic research career than males, which is consistent with the findings for other countries (e.g., Ginther and Kahn 2004; Long et al. 1993). We found that this effect is especially strong immediately after graduation (70% for females vs. 57% for males), less strong during the junior stage (4.8% vs. 3.8%), and disappears during the senior career stage (2.5% vs. 2.3%).[23] However, the share of active female researchers at senior level (associate and full professor) is very low (4.4%). The Japanese government has implemented several policies to try to mitigate the gender gap but it seems that further intervention is needed. We found also that the number of co-grantees decreases the likelihood of exit only after award of a tenured position, suggesting that the effect of individual social

[23] Predictions are based respectively on Model 3 Table 2, Model 1 Table 4, and Model 2 Table 4.

capital may be moderated by seniority.

In relation to institutional factors, as Gaughan and Robin (2004) and Debackere and Rappa (1995) imply, academics in prestigious universities are less likely to exit at the start of their careers (45% for the top seven vs. 65% for the rest) and during the assistant professor period (2.7% vs. 4.6%).[24] Since academic inbreeding is common - particularly in high-ranked universities in Japan (Yamanoi 2007), our result might indicate that opportunities for academics whose careers start in low-ranked universities are unreasonably hampered. From a science policy perspective, mobility across institutions should be facilitated so that talented researchers have more equal access to the institutional capital of prestigious universities, or so that institutional capital at low-ranked universities is boosted. Our results suggest also that the number of researchers in the same workplace reduces exit at either entry or senior (associate and full professor) level. This effect is significant even after controlling for the size of university-level funding input, implying that social capital plays a pivotal role. Importantly, this effect is negligible in the pre-tenure term, suggesting that institutional social capital can help in the identification of entry positions for students, or may help in continuing academic research activities after tenure, but does not play a significant role at assistant professor level.

Among geographical factors, employment opportunities related to teaching jobs at prefecture level facilitates the exit of assistant professors, suggesting academics' move from research to teaching jobs within academia especially during the early phase of their career.

Overall, these results imply that the selection process in Japan is based at least in part, on merit but might be compromised by unfair selection or inequality between genders and among institutions, resulting in unintended exit. We also found some evidence that only

[24] Predictions are based respectively on Model 3 Table 2 and Model 1 Table 4.

senior academics (associate and full professor) are able to benefit from positive individual and institutional network effects. In other words, junior academics searching for tenured positions can be unreasonably forced to exit due to social network effects favoring senior academics. The network effect also extends to the senior academic's students in relation to their first placements, implying that the social capital of senior academics can influence who joins academia.

These findings should be interpreted with care. Due to the structure of the data, the destination of academics after leaving research is not completely clear. The study in this chapter assumes, based on Japanese mobility statistics, that most academics leaving research become university teachers or administrators (rather than industry employees), or exit the labor force. However, the data might include different types of exit and also might include false exit (e.g., death, emigration). This study draws on a large sample in a first attempt to examine the main characteristics of exit from an academic research career. Future research should address the limitations outlined above by studying a smaller, more detailed sample (e.g., survey data). The specificity of our sample is also a limitation. Country and time specificities need to be considered because career progress is heavily dependent on the design of the academic system. Future research should examine exit from an academic research career in different national and historical contexts.

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Table 1 Description of Pre-employment Exit

(A) By Field

PhD Field	#Graduate		#Matched		%Exit
Science	2,073	(15.4%)	1,196	(21.3%)	42.3%
Engineering	2,170	(16.1%)	1,026	(18.3%)	52.7%
Agriculture	841	(6.2%)	403	(7.2%)	52.1%
Pharmaceutical	506	(3.8%)	167	(3.0%)	67.0%
Medicine	6,503	(48.2%)	2,303	(41.0%)	64.6%
Dentistry	1,399	(10.4%)	518	(9.2%)	63.0%
Total	13,492	(100.0%)	5,613	(100.0%)	58.4%

(B) By University

Rank	University	#Graduate		#Matched		%Exit
1	U Tokyo	1,343	(10.0%)	742	(13.2%)	44.8%
2	Kyoto U	986	(7.3%)	543	(9.7%)	44.9%
3	Osaka U	699	(5.2%)	367	(6.5%)	47.5%
4	Tohoku U	605	(4.5%)	312	(5.6%)	48.4%
5	Kyushu U	549	(4.1%)	292	(5.2%)	46.8%
6	Hokkaido U	499	(3.7%)	230	(4.1%)	53.9%
7	Nagoya U	437	(3.2%)	259	(4.6%)	40.7%
	Top 7	5,118	(37.9%)	2,745	(48.9%)	46.4%
10	Tsukuba U	303	(2.2%)	134	(2.4%)	55.8%
20	Keio U	163	(1.2%)	70	(1.2%)	57.1%
30	Tokyo Jikei Med U	114	(0.8%)	52	(0.9%)	54.4%
40	Akita U	91	(0.7%)	28	(0.5%)	69.2%
50	Hamamatsu Med U	70	(0.5%)	29	(0.5%)	58.6%
	Total	13,492	(100.0%)	5,613	(100.0%)	58.4%

Notes: Ranked by the number of PhD graduates.

(C) By Gender

	#Graduate			#Matched			%Exit		%Exit
PhD Field	Male	Female	%Female	Male	Female	%Female	Male	Female	Female/Male
Science	1,909	144	7.0%	1,129	59	5.0%	40.9%	59.0%	1.44
Engineering	2,054	68	3.2%	991	28	2.7%	51.8%	58.8%	1.14
Agriculture	742	77	9.4%	368	34	8.5%	50.4%	55.8%	1.11
Pharmaceutical	454	51	10.1%	153	14	8.4%	66.3%	72.5%	1.09
Medicine	5,876	590	9.1%	2,164	134	5.8%	63.2%	77.3%	1.22
Dentistry	1,278	106	7.7%	488	28	5.4%	61.8%	73.6%	1.19
Total	12,313	1,036	7.8%	5,293	297	5.3%	57.0%	71.3%	1.25

Table 2 Prediction of Pre-employment Exit

	Model 1			Model 2			Model 3		
Individual factors									
graduation year	.007		(.012)	.023		(.020)	.012		(.020)
female	.587	***	(.070)	.567	***	(.072)	.566	***	(.072)
Institutional factors									
top7				-.237	***	(.061)	-.242	***	(.061)
%univ fund				.003		(.008)	-.005		(.008)
ln(#researcher)				-.310	***	(.043)	-.278	***	(.044)
field growth				.141		(.144)	.135		(.145)
field dummies				YES			YES		
Geographical factors									
ln(*#national univ employment*)							-.246	***	(.075)
ln(*#private univ employment*)							.064	**	(.021)
ln(*#industrial employment*)							-.021		(.047)
ln(*#PhD graduate*)							.113	†	(.062)
χ^2 test	74.459	***		796.663	***		832.348	***	
Log likelihood	-9158.37			-8797.26			-8779.42		
N	13492			13492			13492		

Notes: Logit regressions. Unstandardized coefficients (standard errors in parentheses). Two-tailed test. †p<0.1; * p<0.05; ** p<0.01; *** p<0.001.

Table 3 Prediction of Post-employment Exit

	Model 1			Model 2			Model 3		
Individual factors									
pub stock	-.031	***	(.006)	-.034	***	(.006)	-.036	***	(.006)
fund stock	-.022	***	(.005)	-.007		(.005)	-.013	*	(.005)
female	-.256	**	(.079)	.021		(.080)	.171	*	(.081)
job tenure	-.157	***	(.005)	-.025	***	(.005)	.008	†	(.005)
associate prof	-.400	***	(.061)	-.607	***	(.062)	-.499	***	(.063)
full prof	-.707	***	(.094)	-.869	***	(.093)	-.792	***	(.093)
mobility	-1.356	***	(.023)	-.405	***	(.032)	.086	*	(.036)
ln(#cograntee)	.022		(.023)	.204	***	(.024)	.120	***	(.025)
Institutional factors									
top7				-.199	**	(.066)	-.297	***	(.068)
%univ fund				.036	***	(.009)	.018	†	(.010)
ln(#researcher)				-.455	***	(.020)	-.118	***	(.028)
field growth				-1.616	***	(.181)	-.255		(.229)
field dummies				YES			YES		
Geographical factors									
ln(*#national univ employment*)							-.588	***	(.044)
ln(*#private univ employment*)							.083	***	(.023)
ln(*#industrial employment*)							-.327	***	(.038)
ln(*#PhD graduate*)							.399	***	(.042)
χ^2 test	27624.50	***		28218.26	***		28287.25	***	
Log likelihood	-13810.44			-11957.66			-11337.45		
N	81331			81331			81331		

Notes: Complementary log-log model. Unstandardized coefficients (standard errors in parentheses). Two-tailed test. †p<0.1; * p<0.05; ** p<0.01; *** p<0.001.

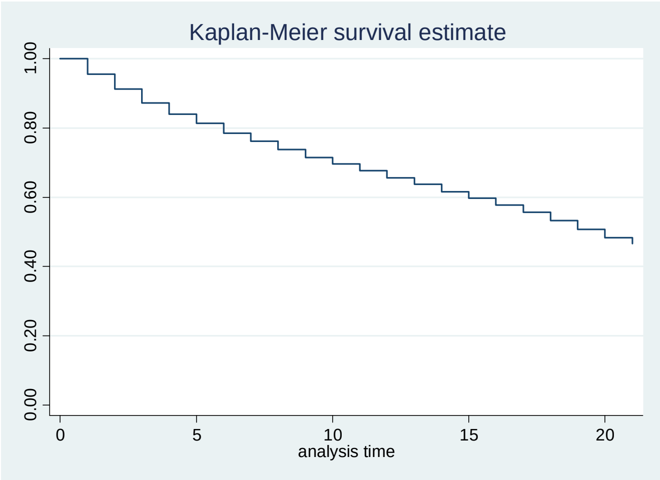
Table 4 Prediction of Post-employment Exit by Career-Stage

	Model 1 (pre-tenure)			Model 2 (post-tenure)		
Individual factors						
pub stock	-.029	***	(.008)	-.040	***	(.009)
fund stock	.003		(.007)	-.033	***	(.010)
female	.187	*	(.088)	-.028		(.213)
job tenure	.009		(.006)	.021	**	(.008)
full prof				-.137		(.094)
mobility	.142	**	(.048)	.022		(.059)
ln(#cograntee)	.164	***	(.029)	-.098	*	(.048)
Institutional factors						
top7	-.342	***	(.075)	-.107		(.187)
%univ fund	.007		(.011)	-.007		(.029)
ln(#researcher)	.025		(.037)	-.298	***	(.045)
field growth	-.289		(.259)	-.113		(.488)
field dummies	YES			YES		
Geographical factors						
ln(*#national univ employment*)	-.709	***	(.051)	-.383	***	(.081)
ln(*#private univ employment*)	.077	**	(.026)	.070		(.053)
ln(*#industrial employment*)	-.298	***	(.043)	-.397	***	(.076)
ln(*#PhD graduate*)	.456	***	(.049)	.372	***	(.078)
χ^2 test	19652.04	***		8066.32	***	
Log likelihood	-8298.86			-2933.41		
N	52584			28747		

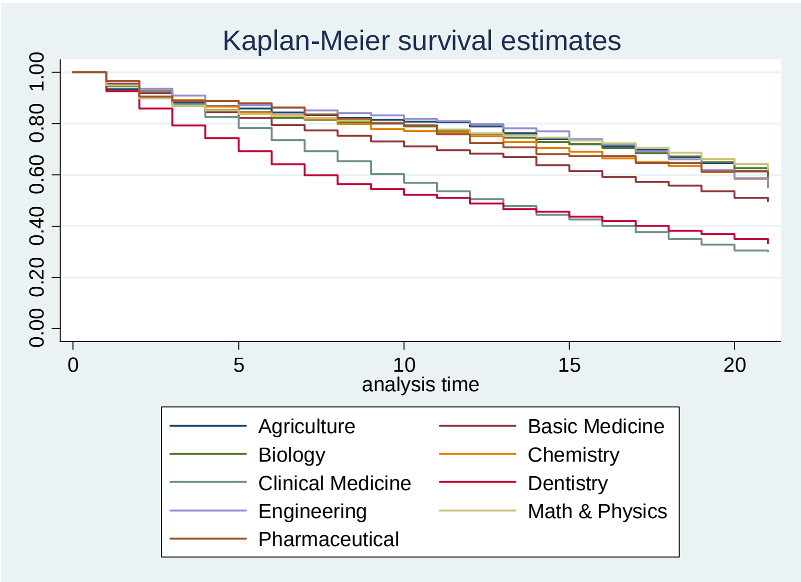
Notes: Complementary log-log model. Unstandardized coefficients (standard errors in parentheses). Two-tailed test. †p<0.1; * p<0.05; ** p<0.01; *** p<0.001.

Figure 1 Survivor functions (N = 5,613)

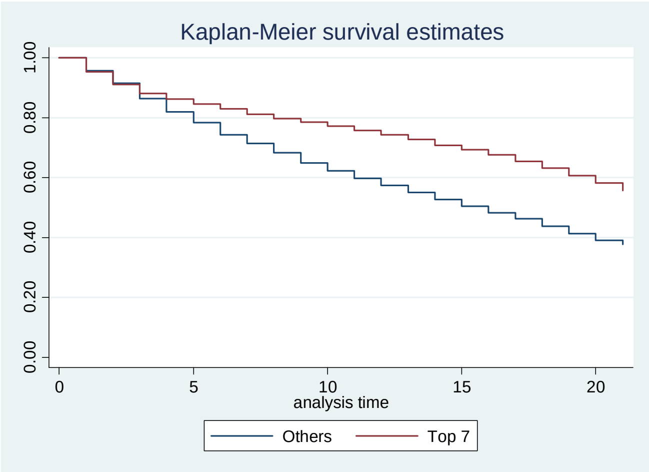
(A) Whole Sample



(B) Scientific fields



(C) PhD Universities (Top 7 vs. Others)



(D) Gender (female vs. male)

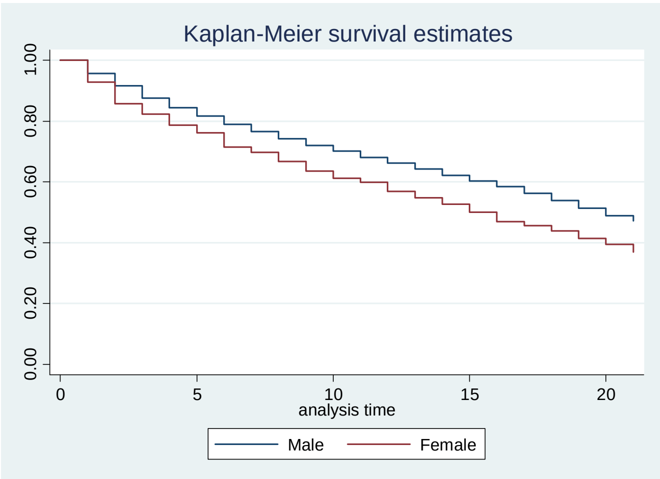
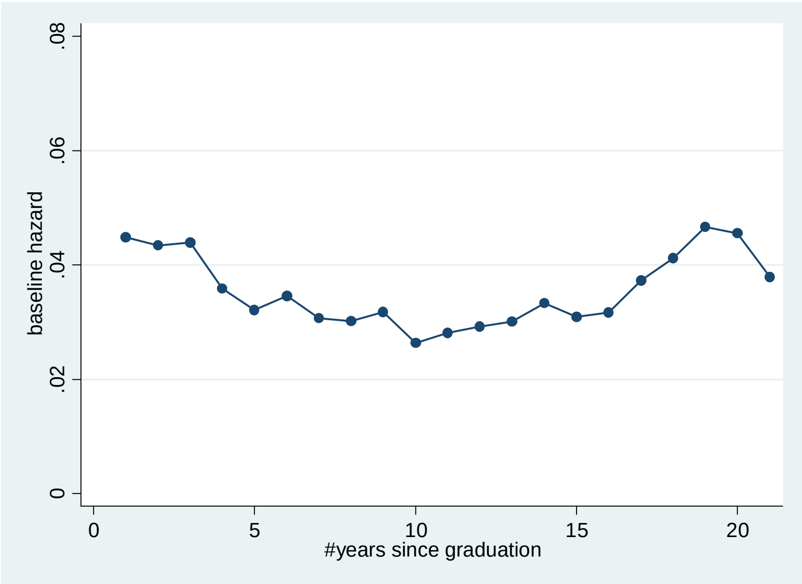
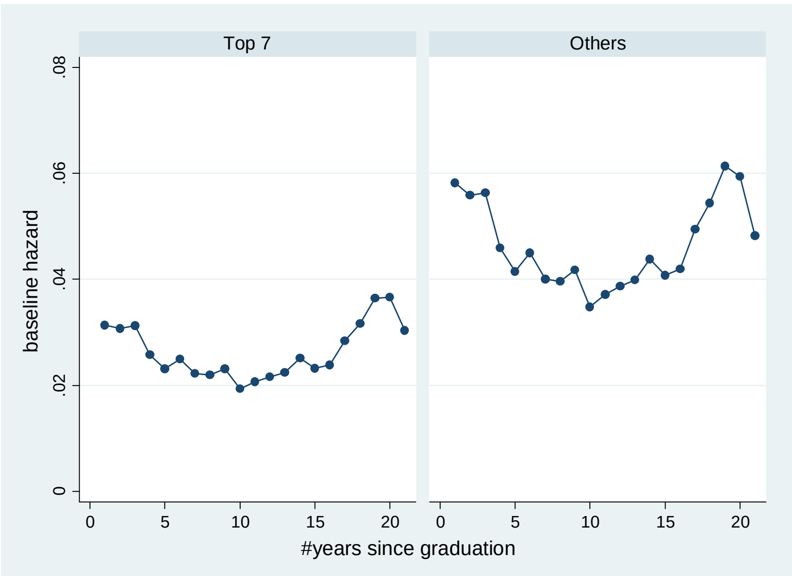


Figure 2 Baseline hazard function

(A) Whole Sample



(B) PhD Universities (Top 7 vs. Others)



(C) Gender (Male vs. Female)

Appendix 1 Descriptive Statistics and Correlation

(A) Pre-employment Exit

	Variable	Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10
1.	*pre-employment dropout*	.58	.49	.00	1.00										
2.	*graduation year*	1987	1.41	1985	1989	.00									
3.	*female*	.08	.27	.00	1.00	.08	.02								
4.	*top7*	.38	.49	.00	1.00	-.19	-.02	-.02							
5.	*%univ fund*	4.24	4.48	.00	26.48	-.18	-.02	-.01	.70						
6.	*ln(#researcher)*	3.72	1.03	.69	5.93	-.19	.04	-.03	.71	.79					
7.	*field growth*	.13	.19	-.10	.53	-.01	-.76	-.01	.04	.04	-.02				
8.	ln(*#national univ employment*)	7.81	.91	5.06	8.92	-.08	-.02	.00	.31	.48	.40	.03			
9.	ln(*#private univ employment*)	7.78	2.21	.00	10.21	-.03	-.01	.00	.20	.38	.29	.01	.81		
10.	ln(*#industrial employment*)	7.85	.83	5.81	8.76	-.02	-.02	.01	.12	.31	.23	.02	.78	.87	
11.	ln(*#PhD graduate*)	5.30	1.33	.69	7.04	-.06	.06	.00	.29	.46	.37	-.03	.95	.88	.83

Notes: N = 13,492. For time-variant variables, we use the value of each variable at *graduation year*.

(B) Post-employment Exit

	Variable	Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	*post-employment dropout*$_{it}$	.03	.18	.00	1.00																
2.	*pub stock*	.27	7.16	-12.88	100.94	-.04															
3.	*fund stock*	.50	7.76	-13.42	186.16	-.04	.69														
4.	*female*	.05	.21	.00	1.00	.01	-.02	-.04													
5.	*job tenure*	7.88	6.47	1.00	77.00	.01	.02	.03	.01												
6.	*associate prof*	.65	.48	.00	1.00	.04	-.20	-.18	.05	-.22											
7.	*full prof*	.24	.43	.00	1.00	-.03	.05	.05	-.05	.14	-.76										
8.	*mobility*	1.26	.79	.00	8.00	-.01	.05	.03	-.03	-.27	-.41	.24									
9.	*ln(#cograntee)*	1.38	1.16	.00	5.01	-.02	.31	.33	-.03	.33	-.52	.31	.32								
10.	*top7*	.35	.48	.00	1.00	-.05	.11	.15	-.01	.03	.07	-.04	-.14	.06							
11.	*%univ fund*	3.69	4.25	.00	26.48	-.04	.11	.17	.01	.03	.09	-.06	-.15	.05	.72						
12.	*ln(#researcher)*	3.79	1.24	.69	6.06	-.02	.12	.17	-.02	.11	.08	-.05	-.18	.12	.64	.73					
13.	*field growth*	.04	.11	-.20	.73	-.01	-.01	-.01	.00	-.11	.17	-.11	-.17	-.18	.02	.03	.02				
14.	ln(*#national univ employment*)	7.81	.91	5.06	9.05	-.02	.05	.10	.01	.07	.06	-.06	-.08	.04	.33	.45	.32	.00			
15.	ln(*#private univ employment*)	7.82	2.08	.00	10.49	-.01	.04	.08	.00	.08	.02	-.03	-.04	.06	.24	.37	.24	-.02	.83		
16.	ln(*#industrial employment*)	7.75	.86	5.75	8.79	-.01	.02	.05	.01	.02	.08	-.07	-.07	-.02	.18	.31	.18	.01	.79	.88	
17.	ln(*#PhD graduate*)	5.74	1.44	.69	8.17	-.02	.06	.10	.01	.20	-.08	.02	.01	.18	.29	.40	.30	-.08	.92	.88	.81

Notes: N = 81,331.

Appendix 2 Summary of Predictions by Career-Stage by Field

(A) Pre-employment Exit

	All fields	Science	Engineering	Agriculture	Pharmaceutical	Medicine	Dentistry
Individual factors							
graduation year							+
female	+++	+++				+++	+
Institutional factors							
top7	- - -		- -	- -	- -		-
%univ fund		-	+++				- - -
ln(#researcher)	- - -		- - -			- - -	
field growth							
Geographical factors							
ln(*#national univ employment*)	- - -					-	
ln(*#private univ employment*)	++					+++	++
ln(*#industrial employment*)						-	-
ln(*#PhD graduate*)	+						

Notes: +/- $p<0.05$; ++/-- $p<0.01$; +++/--- $p<0.001$.

(B) Post-employment Exit

	All fields		Math& Physics		Biology		Chemistry		Engineering		Agriculture		Pharma-ceuticals		Basic Medicine		Clinical Medicine		Dentistry	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Individual factors																				
pub stock	--	---		---	-	-				-						-			-	+
fund stock		---					+			-	++		+++				-			-
female	+										+									
job tenure		++									+++									
full prof	n.a.		n.a.	+	n.a.		n.a.		n.a.		n.a.		n.a.		n.a.		n.a.	---	n.a.	
mobility	++		+++		+				+++		+									
ln(#cograntee)	+++	-	---	-					--								+++		++	
Institutional factors																				
top7	---								-							++			--	
%univ fund					+										+		--		-	
ln(#researcher)		---		--						---						-		--		
field growth						+	-					-								
Geographical factors																				
ln(*#national univ employment*)	---	---			-		-				-	-	-		-		---	-	--	
ln(*#private univ employment*)	++																++			
ln(*#industrial employment*)	---	---				---	-					-				-	-			
ln(*#PhD graduate*)	+++	+++		+					+				+				+			

Notes: +/- p<0.05; ++/-- p<0.01; +++/--- p<0.001. Column 1 corresponds to pre-tenure exit and column 2 to post-tenure exit.