RESEARCH ARTICLE

Analyzing academic mobility of U.S. professors based on ORCID data and the Carnegie Classification

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an open access journal

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Citation: Yan, E., Zhu, Y., & He, J. (2020). Analyzing academic mobility of U.S. professors based on ORCID data and the Carnegie Classification. *Quantitative Science Studies*, *1*(4), 1451–1467. https://doi.org/10.1162/qss_a_00088

DOI:
https://doi.org/10.1162/qss_a_00088

Supporting Information:
https://doi.org/10.1162/qss_a_00088

Received: 31 March 2020
Accepted: 16 July 2020

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Handling Editor:
Ludo Waltman

Keywords: academic mobility, Carnegie Classification, gender, ORCID

ABSTRACT

This paper uses two open science data sources—ORCID and the Carnegie Classification of Institutions of Higher Education (CCIHE)—to identify tenure-track and tenured professors in the United States who have changed academic affiliations. Through a series of data cleaning and processing actions, 5,938 professors met the selection criteria of professorship and mobility. Using ORCID professor profiles and the Carnegie Classification, this paper reveals patterns of academic mobility in the United States from the aspects of institution types, locations, regions, funding mechanisms of institutions, and professors' genders. We find that professors tended to move to institutions with higher research intensity, such as those with an R1 or R2 designation in the Carnegie Classification. They also tend to move from rural institutions to urban institutions. Additionally, this paper finds that female professors are more likely to move within the same geographic region than male professors and that when they move from a less research-intensive institution to a more research-intensive one, female professors are less likely to retain their rank or attain promotion.

1. INTRODUCTION

Academic moves are a vital component of academic life. The collective patterns of academic mobility are central to scholarly communication research. Studies of such patterns have important implications for developing a better understanding of the higher education landscape and directly inform assessments of the scientific workforce and the scientific enterprise.

There is already a vast collection of literature that analyzes academic mobility. Current knowledge is ascertained primarily from two levels of mobility: the country level and the affiliation level. A common approach is first analyzing bibliographic records, then identifying author affiliations, and finally, aggregating affiliations to countries. By following this approach, the current literature has revealed important facets of academic mobility, including its patterns, its determinants, and its impact on research productivity and career paths. Research has shown that mobile researchers tend to be more productive and that researchers move to institutions with better opportunities to undertake their research (Sugimoto, Robinson-Garcia, et al., 2017). Accordingly, the international mobility of researchers has exacerbated the "brain drain" effect in which well-trained researchers are more likely to cluster in places with already abundant human capital (Docquier, Marfouk, et al., 2012; Docquier & Rapoport, 2012).

Despite these advances, one major gap remains: The country-level studies have only provided broad-stroke depictions of academic mobility, and the high-level findings are usually insufficient

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to understand the impact of academic moves upon individual scientists. Furthermore, for affiliation-level studies, there is minimal treatment of authors, and thus we are unable to differentiate between types of authors such as students, technicians, and professors of different ranks. Because authors are a broad category of personnel in the scientific workforce, they cannot be clearly mapped into meaningful organizational structures in higher education. The goal of this paper is to accurately identify U.S. tenure-track and tenured professors via a comprehensive open science data repository (ORCID) and then link these individuals to institution-level profiles from the Carnegie Classification of Institutions of Higher Education (CCIHE). The integrated data will allow for clear and robust examination of academic mobility, institutional stratification, and the role of organizational factors in shaping academic mobility.

Prior literature showed that professors tend to move to institutions with more abundant research resources and greater human capital, such as their peers' reputations (Docquier et al., 2012). The level of research-related resources can be measured by the research intensity designation of the Carnegie Classification (Indiana University Center for Postsecondary Research, 2018). Therefore, we hypothesize that professors are more likely to move to more research-intensive institutions (such as those with an R1 designation in the Carnegie Classification). In addition, due to the two-body problem, finding jobs for a professor's partner can be quite challenging in rural locations or small towns. According to a report by the Clayman Institute at Stanford University, more than 70% of professors are in dual-career relationships and about half of them are partnered with another academic (Schiebinger, Henderson, & Gilmartin, 2008). Therefore, it is reasonable to hypothesize that professors are more likely to move to institutions located in larger metropolitan areas so that their partners can have better access to job opportunities, and that together, they can have a better quality of life. Based on these prior observations, we make the following hypotheses:

- H1: U.S. professors tend to move from institutions with lower research intensity to those with higher research intensity.
- H2: U.S. professors tend to move from institutions located in towns or rural regions to those located in cities.

Gender is an important mediator of academic moves. Prior research found that female researchers tend to move less than male researchers as they advance towards their later career stages (Hopcroft, Khan, et al., 2004; McLean, Morahan, et al., 2013). It is also shown that decisions to move manifest through researchers' gendered social networks—female researchers are less likely to move than men when either have adolescents at home (Azoulay, Ganguli, & Zivin, 2017). As a result, female researchers may be less likely to make long-distance moves that interrupt their family life. Based on the prior work, we make the following hypothesis:

- H3: female professors in the United States are more likely to move within the same geographic region than male professors.

By verifying these hypotheses, this paper aims to reveal patterns of academic mobility using a large sample of U.S. tenure-track and tenured professors. The results illustrate key aspects of academic mobility along the dimensions of institutional profiles (Carnegie Classifications and institution locations and regions) as well as professor profiles (gender and rank). Therefore, the project will be of value to scholarly communication research and contribute to our understanding of academic mobility within the U.S. science enterprise.

2. LITERATURE REVIEW

2.1. Patterns and Characteristics of Mobility

Quantitative studies have described the characteristics of national inflows and outflows at a global level (Ioannidis, 2004; Sugimoto et al., 2017; Van Der Wende, 2015). In a study of

1,523 highly cited scientists, Ioannidis (2004) found that 31.9% did not reside in their country of birth, but great variability has been shown across developed countries and across different disciplines in the proportions of foreign-born scientists. A more recent study of 16 million scientists identified about 4% as deemed mobile according to the countries of their affiliations in publications (Sugimoto et al., 2017). The international circulation of scientists is making human capital scarcer where it is already scarce and more abundant where it is already abundant, thereby contributing to increasing inequality across countries (Docquier et al., 2012; Docquier & Rapoport, 2012). The United States is the top destination country for mobile scientists and is still perceived as a strong destination for advancing one's research career (Bland & Van Noorden, 2012; Franzoni, Scellato, & Stephan, 2012; Ganguli, 2015; Scellato, Franzoni, & Stephan, 2015; Veugelers, Van Bouwel, & Geuna, 2015). A major reason that individuals came to the United States for educational training is the prestige of its programs and career prospects (Stephan, Franzoni, & Scellato, 2016). However, foreign-born American scientists are likely to return home when their country develops a strong infrastructure to support research in their disciplines (Zucker & Darby, 2014).

Elite scientists migrate systematically towards nations with large research expenditure (Hunter, Oswald, et al., 2009; Kato & Ando, 2017). Mobility occurs more among potential elite scientists than among established elite researchers (Laudel, 2005). Elite scientists also tend to move from places with few peers in their discipline to places with many, which leads to a concentration of star scientists over time (Zucker & Darby, 2014). Mobility between universities with different levels of prestige has also been investigated (Allison & Long, 1987; Debackere & Rappa, 1995). For instance, over time, scientists in the field of neural networks tend to move from more prestigious universities to less prestigious universities (Debackere & Rappa, 1995). However, physicists from elite institutions are more likely to move to other elite institutions (Deville, Wang, et al., 2014). Scientists are more likely to move when their productivity (Azoulay et al., 2017) and scientific impact (Sugimoto et al., 2017) are high. Emigrants were much more likely to have a foreign coauthor and to have published in an international journal (Ganguli, 2015).

2.2. Determinants of Mobility

Mobility is driven by a variety of reasons that can be academic, job-related, or family-related and personal (Auriol, 2010). Factors related to availability and quality of career opportunities and the ease of re-entry into the home labor market are critical for return decisions (Ackers & Gill, 2008; Casey, Mahroum, et al., 2001). Personal and professional linkage to the home country can contribute to the probability of return (Baruffaldi & Landoni, 2012): This can include collaborations with home-country scientific journals, mentoring, visiting, business relationships, and so forth. A reasonable salary level should be guaranteed, but the return decisions of researchers and scientists are primarily shaped by factors such as the quality of the research environment, professional reward structures, and access to state-of-the-art equipment (Thorn & Holm-Nielsen, 2006). Although the science and technology infrastructure takes precedence over quality of life, both are influential factors in academics' mobility decisions (Siekierski, Lima, & Borini, 2018a; Siekierski, Lima, et al., 2018b).

Gender also plays an important role in mobility. Although more women are involved in international migration, especially for high-skilled migrants originating from developing countries (Docquier et al., 2012), female scientists tend to move less than men as they get older or are in later career stages (Hopcroft et al., 2004; McLean et al., 2013). They also show a more pronounced willingness to follow their spouse than do their male peers (Docquier et al., 2012). Azoulay et al. (2017) found that elite scientists, particularly those who are female, are less likely to move when they have recently received NIH funding and appear to be unwilling to move when their children are in high school.

2.3. Mobility, Productivity, and Career Advancement

Researchers with foreign work experience tend to publish more articles in high-impact-factor journals, both in general and as first or last authors, than their counterparts who have not been abroad (Jonkers & Cruz-Castro, 2013). Migrants perform at a higher level than domestic scientists with or without prior experience of international mobility (Franzoni, Scellato, & Stephan, 2014; Halevi, Moed, & Bar-Ilan, 2016). Velema (2012) argued that the impact of return scholars is likely to vary according to the quality of the foreign institute to which they have been affiliated. Countries may also benefit from the mobility: Wagner and Jonkers (2017) found that countries that welcome international researchers and encourage cross-border collaboration tend to produce papers with high scientific impact.

For interuniversity mobility, counts of published articles had statistically significant but slight effects on gains or losses in job prestige (Allison & Long, 1987). Graduate school prestige was also a significant determinant of an early entrant's subsequent academic appointment (D'Aveni, 1996; Debackere & Rappa, 1995; Miller, Click, & Cardinal, 2005; Williamson & Cable, 2003). However, graduate school prestige has no significant effect on mobility beyond the early career stage (about 5 years) (Debackere & Rappa, 1995) and cannot stop the downward cascading of affiliation prestige that results from moving to a university with relatively low prestige from a university with higher prestige (Miller et al., 2005). Apart from prestige, the moves of elite scientists are partly driven by the scope for improvement in the quality of their peer environment (Azoulay et al., 2017). Mobile researchers who changed affiliations during their scientific career tend to have slightly higher publication and citation rates than other researchers (Aksnes, Rørstad, et al., 2013). However, the number of affiliations a researcher moves to, whether two or three, might not make a significant difference (Halevi et al., 2016). McLean et al. (2013) found a positive relationship between geographic mobility and advancement in administrative position. Tohmo and Viinikainen (2017) found that nonfrequent intersectoral mobility was related to higher earnings, whereas frequent mobility was typically associated with lower subsequent earnings. Mobility from the university to the private sector may bring economic gains in the natural sciences, whereas in the social sciences, the earnings returns from mobility are statistically insignificant.

3. DATA AND MATERIALS

3.1. Identifying Professors with Academic Moves in ORCID

The 2018 version of ORCID data was collected through Figshare (Blackburn, Brown, et al., 2018). We limited researchers to U.S. tenure-track or tenured professors, meaning that all affiliations on a researcher's profile must be in the United States (or its territories) and any professorship position needs to be an assistant, associate, or full professorship. The reasons that we only focus on U.S. professors are twofold. First, professorship is the only reliable category of titles in ORCID, and even for this category, we had to implement a series of heuristics to ensure the accurate grouping of titles and ranks. For other categories of researchers, it is not reliable to use ORCID to extract their positions. Second, we restricted ORCID researchers to U.S. professors only for the reason that higher education systems in different countries have varied norms and expectations. To mitigate the confounding factors arisen from the differences, we limited the scope to U.S. professors. We also excluded professors (n = 3,778) who had both U.S. and outside U.S. affiliations for the same reason outline above.

Because ORCID does not use controlled vocabulary, navigating researcher titles and classifying professor ranks poses a challenge. To ameliorate this, we developed a simple yet effective rubric to identify tenure-track and tenured professorship:

- First, all titles were uppercased, and titles that do not include "PROF" were filtered out.

- Second, we removed titles that include “visiting,” “adjunct,” “research,” and “clinical.” All titles were then manually classified into three ranks based on whether they include the keywords “assistant,” “associate,” and “full.”’ Title abbreviations such as “ASSOC” and “ASST” also exist. To capture them, we sorted all the titles alphabetically and manually checked abbreviations (e.g., “AST,” “ASSO”) and classified them.
- Third, to address typos such as “ASSSISTANT,” “ASOCIATE,” we developed the following rubric. “AS” was used to differentiate full professor-related titles from the others, and “SO” was used to differentiate assistant professors from the others; the rationale being that “AS” is not likely to be included in the full professor-related titles and assistant professor-related titles tend to not include “SO.” After applying this rubric, there were still many titles that could not be categorized into the three ranks because of endowment titles (e.g., JAMES B. DUKE PROFESSOR). We manually reviewed each category and merged endowment titles into their respective categories.

To ensure data recency, only profiles that were last updated in October 2016 or later were included. In total, 47,044 professors met the criteria; among them, 38,426 did not have a change in rank or organization and were not included in the current analysis. The remaining 8,618 professors made 12,671 changes in rank or organization. These records had a few anomalies that required treatment.

- First, we removed 1,191 records that had the starting year of the second position earlier than the end year of the first position (first position is defined as the one with the earliest start year among all positions for a professor).
- Second, we removed 102 records with multiple coaffiliations that could be mistaken for an organization change (e.g., Assistant Professor at Harvard University (since 2015) and Broad Institute [since 2017]).
- Third, for the remaining 11,378 records, we removed 28 records with no start year given for the second position and 456 records with only endowment changes (e.g., from professor to distinguished professor). The intermediate data set contains 10,894 position changes.
- Last, a gender classifier called genderPredictor[1] was applied to identify professors’ genders. The classifier is based on a naïve Bayes model that uses the U.S. Social Security Administration name database as the input training data.

3.2. Linking ORCID with Carnegie Classification of Institutions of Higher Education (CCIHE)

ORCID data itself contains limited metadata about each institution. Therefore, it was necessary to link the data with an external source that provides richer institution information. We identified a valuable source: the Carnegie Classification of Institutions of Higher Education (CCIHE). CCIHE provides a set of reliable and comprehensive lists of classifications to more than 4,000 higher education institutions in the United States The key classification produced by CCIHE is the Basic Classification (referred to as Carnegie Classification in this paper) that assigns an institution based on the level of research intensity and the level of degree granted. When linking the ORCID data with CCIHE, we merged medical schools, hospitals, departments, and affiliated schools given in the ORCID data into their respective parent universities. If an ORCID record did not specify the campus of a university, its main campus (flagship campus) was assumed. There are a small number of records (238) with affiliations that cannot be found in CCIHE, including companies, laboratories, and hospitals that do not have an affiliated university.

[1] https://github.com/sholiday/genderPredictor

We also manually formatted ORCID organization data so that institutions could be properly matched. For instance, a mention of "Indiana University Bloomington" in an ORCID record would be formatted as "Indiana University-Bloomington" to facilitate matching in CCIHE. The remaining 10,656 records are fully matched with CCIHE; among these, 4,718 had only a rank change and 5,938 had an organization change (2,278 had both rank and organization changes and 3,660 had only an organization change) and are included in this analysis. The data is accessible at figshare (Yan, 2020). Figure 1 uses histograms to show the distribution of academic change: In the subgraph to the left (All), an academic change can be a promotion, an academic move, or both; for the subgraph to the right (Moved), an academic change is an academic move. As expected, most professors made only one academic move and only 2.5% of the professors made three or more moves.

In CCIHE, the following variables were collected for each institution: Carnegie Classification (2018 version), institution locale, institution region, institution sector, and institution minority serving status (including historically Black colleges and universities, tribal institutions, Hispanic-serving institution, and other minority-serving institutions). These variables highlight the characteristics of higher education institutions and allow for more meaningful examinations of academic move patterns. There are more than 30 Carnegie Classification level codes to measure the level of research intensity and the level of degree granted (Indiana University Center for Postsecondary Research, 2018); for ease of presentation and analysis, we merged level codes 1–13 to Associate, 14 and 21–23 to Baccalaureate, 18–20 as Master, and 24–32 as Special Focus Four-Year, while keeping codes 15 to 17 as separate categories. They are R1 (Doctoral Universities—Very high research activity), R2 (Doctoral Universities—High research activity), and R3 (Doctoral/Professional Universities). The full list of all Carnegie Classification codes can be seen in the Supplementary Information Table S1. For locale types, we kept the three classes for cities: City Large, City Midsize, and City Small, while merging different town types to Town, suburban types to Suburban, and rural types to Rural.

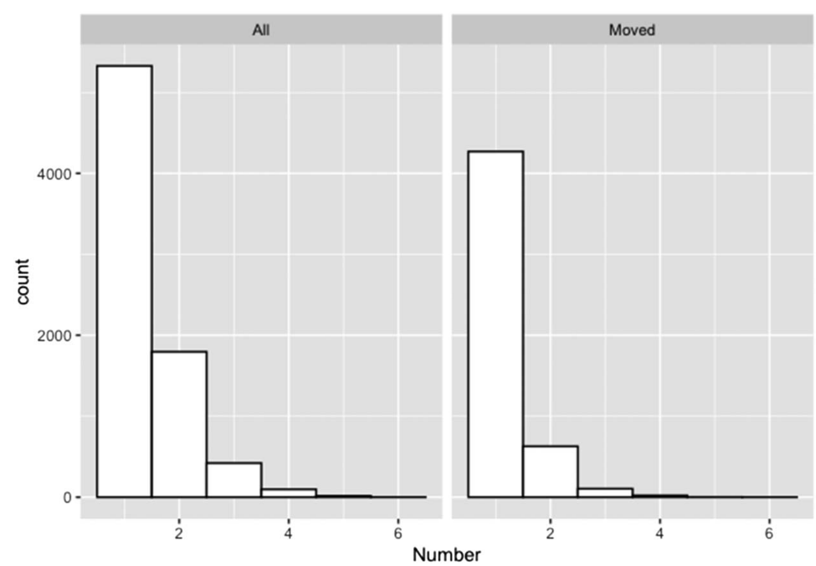

Figure 1. Histograms of the distributions of academic change. In the subgraph to the left (All), an academic change can be a promotion, an academic move, or both; for the subgraph to the right (Moved), an academic change is an academic move.

We now turn to issues of data representation. ORCID is a self-reporting data repository, and the data set used in this study is essentially a sample of academic moves of U.S. tenure-track or tenured professors. Therefore, it is important to recognize potential sampling biases. We examine data representation issues in the following ways: first, in the 10,656 fully matched records, we identified 1,162 distinct institutions from a combination of both move origin and destination institutions. The breakdown of these institutions based on the Carnegie Classification is shown in Table 1.

All 131 R1 institutions are represented in the current data set; R2 and R3 institutions are also well represented. About half of the master's-level institutions and a third of the baccalaureate-level institutions are represented, whereas associate-level and special focus 4-year institutions have comparatively inadequate representations. None of the 34 tribal institutions is represented in the data set. Second, a third of the public (572 of 1653) and of the private nonprofit institutions (577 of 1742) in CCIHE are represented in the current data set, whereas only 1% of for-profit institutions (13 out of 929) are represented.

Third, of the 1,162 institutions represented in this data set, CCIHE includes the number of tenure-track or tenured faculty for 257 institutions (2016 data), all of which are R1 or R2 institutions. The top five most represented institutions are Rockefeller University (29% of its tenure-track or tenured professors are represented in the current data set), Harvard University (16%), Jefferson (Philadelphia University + Thomas Jefferson University) (15%), Vanderbilt University (15%), and Iowa State University (14%). A histogram presentation of the distribution of the ratios of professors represented in the data set is shown in Supplementary Information Figure S1. On average, among these 257 institutions, 6% of tenure-track or tenured faculty are represented in this data set. We can safely assert that the data set is skewed towards research-oriented institutions. Lastly, it is important to note that we are not measuring the number of professors that an institution has at a particular point in history, which is attributable to a slew of factors, but rather institution-level academic moves. This is a much more meaningful measurement because the total number of institutions is the same before and after moving, and for any move there must be both an origin

Table 1. Breakdown of institutions based on Carnegie Classifications

Classification	In the data set	CCIHE	Percentage
R1 Doctoral Universities Very high research activity	131	131	100
R2 Doctoral Universities High research activity	132	135	97.8
R3 Doctoral/Professional Universities	113	151	74.8
Master	381	684	55.7
Baccalaureate	256	838	30.6
Associate	35	1,432	2.4
Special Focus Four-Year	114	919	12.4
Tribal	0	34	0.0
Total	1,162	4,324	26.9

and a destination. Therefore, the data set used in this study can be considered as a closed system in which actors (i.e., professors) make decisions about moving.

4. RESULTS

In this section, we present results on the patterns of 5,938 academic moves that have an organization change. Among them, 30% of the moves are made by female professors and 70% are by male professors. There are 11 ORCID records without names or bibliographic data from which to identify gender by the time we collected the data, so the total number of professors in the gendered columns is 5,927. For statistics on rank changes for professors without academic moves, see Supplementary Information Table S2.

4.1. Patterns of Rank Change in Academic Moves

We first report the rank changes after an academic move (Table 2).

Professors in about 60% of the moves retained their rank, and in 26% of the moves they received promotion, either from assistant to associate or from associate to full professor. In about 10% of the moves, they received promotion from assistant to full professor. Demotion only occurred in 2% of the moves. The percentages for different types of rank changes are similar for female and male professors.

Next, we examine the changes in affiliation types defined by the Carnegie Classification of higher education institutions. The top 10 most common change types are shown in Table 3. A complete list can be found in the Supplementary Information Table S3.

Half of the time, the new institutions that professors moved to have the same classification as the old institutions from which they move. About 8% of the time, professors moved from an R2 institution to an R1 institution and 7% for from R1 to R2. Female professors moved from R2 and master-level institutions to R1 institutions at a slightly higher rate, whereas the percentage in other affiliation types is similar between female and male professors. We can cross-check institution type change with rank change (Table 4) and answer the questions: When did female professors move to a new institution with a different Carnegie Classification? Did they keep their rank, get promoted, or be demoted?

When female professors moved from an R1 institution to an R2 institution, they were promoted 3.1% more (45.8% for female professors vs. 42.7% for male professors) than their male

Table 2. Percentage of rank changes after academic moves for female and male professors

Rank change	F	M	Total
No change	1,110 (61.1%)	2,544 (61.9%)	3,660 (61.7%)
Up by one rank	483 (26.6%)	1,075 (26.2%)	1,563 (26.3%)
Up by two ranks	174 (9.6%)	418 (10.2%)	592 (10.0%)
Down by one rank	40 (2.2%)	62 (1.6%)	102 (1.7%)
Down by two ranks	9 (0.5%)	12 (0.3%)	21 (0.4%)

Note: Up by one rank: from assistant to associate or from associate to full; up by two ranks: from assistant to full; down by one rank: from associate to assistant or from full to associate; down by two ranks: from full to assistant.

Table 3. Percentage of affiliations' Carnegie Classification change before and after academic moves for female and male professors (top 10 based on percentage of change)

Carnegie Classification change	F	M	Total
No change	907 (49.9%)	2,201 (53.5%)	3,116 (52.5%)
R2 to R1	151 (8.3%)	302 (7.4%)	453 (7.6%)
R1 to R2	120 (6.6%)	274 (6.7%)	395 (6.7%)
Special focus 4-year to R1	76 (4.2%)	212 (5.2%)	289 (4.9%)
R1 to Special focus 4-year	65 (3.6%)	192 (4.7%)	258 (4.3%)
Master to R2	53 (2.9%)	117 (2.9%)	170 (2.9%)
Master to R1	67 (3.7%)	98 (2.4%)	165 (2.8%)
R1 to Master	35 (1.9%)	70 (1.7%)	105 (1.8%)
R2 to Master	35 (1.9%)	61 (1.5%)	96 (1.6%)
Baccalaureate to Master	32 (1.8%)	50 (1.2%)	82 (1.4%)

counterparts. Meanwhile, when female professors moved from an R2 institution to an R1 institution, they were demoted at a rate 2.7% higher (4.7% for female professors vs. 2% for male professors) and were promoted 2% less (28.5% for female professors vs. 30.5% for male professors) than male professors. The results paint a different picture for female professors who moved to less research-intensive institutions (R2) and those who moved to more research-intensive institutions (R1). The results show that when moving to more research-intensive institutions, female professors are less likely to retain their rank or get promoted when compared with male professors.

Table 4. Rank change vs. Carnegie Classification change for female and male professors

Rank change/Carnegie Classification change	Down by 1 rank (%)		Down by 2 ranks (%)		No change (%)		Up by 1 rank (%)		Up by 2 ranks (%)	
	F	M	F	M	F	M	F	M	F	M
R1 to R1	0.6	0.5	0.1	0.1	61.2	62.8	28.2	25.7	10.0	10.9
R1 to R2	0.0	0.7	0.0	0.0	54.2	56.6	33.3	30.3	12.5	12.4
R1 to Other	0.0	0.3	0.7	0.6	46.0	52.1	41.6	35.2	11.7	11.8
R2 to R1	4.0	2.0	0.7	0.0	66.9	67.6	19.2	23.2	9.3	7.3
R2 to R2	5.4	1.6	0.0	0.0	60.7	68.6	25.0	22.6	9.0	7.3
R2 to Other	3.7	1.4	0.0	0.0	60.5	52.8	28.4	28.9	7.4	16.9
Other to R1	2.2	4.0	0.5	0.5	71.0	64.0	21.5	23.5	4.9	8.0
Other to R2	5.5	3.7	3.6	0.5	59.1	69.0	14.6	20.6	17.3	6.4
Other to Other	5.6	3.3	0.4	1.0	63.0	60.5	23.9	26.2	7.2	9.1

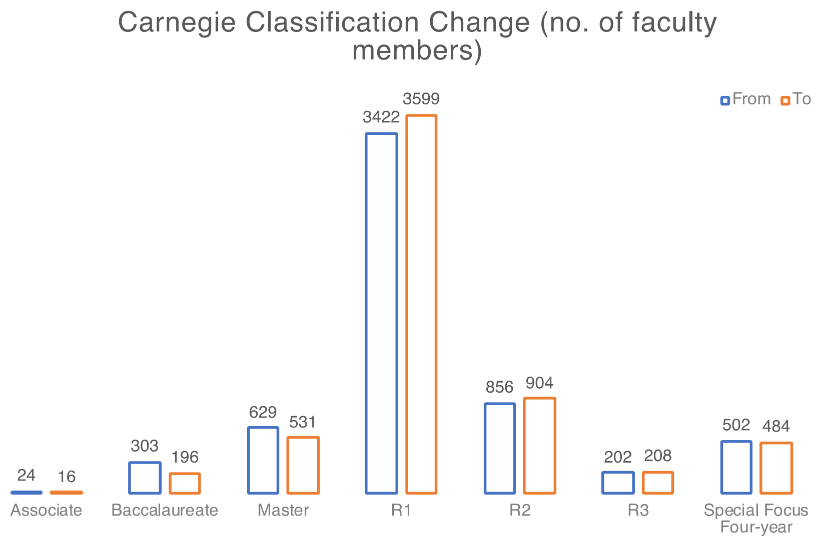

Figure 2. Number of faculty members before and after academic moves for seven types of Carnegie Classification institutions.

We show the Carnegie Classification for institutions before and after moving (Figure 2) and pairwise moves between different types of Carnegie Classifications (Figure 3).

Figure 2 illustrates that professors tend to move from nondoctoral-level institutions (Baccalaureate-, Master-, and Special Focus Four-Year-institutions) to doctoral-level institutions (R1, R2, and R3).

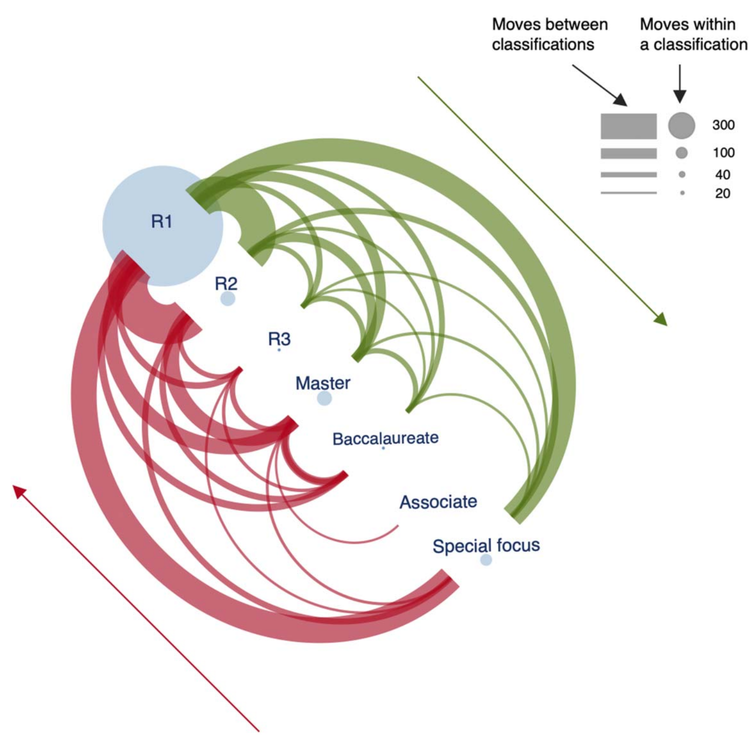

Figure 3. An illustration of pairwise moves between different types of institutions based on the Carnegie Classification.

Figure 3 shows that the most frequent moves are between R1 and R2 and between R1 and Special focus institutions. Special focus institutions are those specializing in health professions, engineering, and so forth. More professors move from baccalaureate- and master-level institutions to R1 institutions than from R1 institutions to the two types of institutions, as shown by the thickness of the arcs. This result, in conjunction with the observations made in Figure 2, supports our first hypothesis.

4.2. Geographic Patterns of Academic Moves

We examine the changes in affiliation locale defined by CCIHE. The top 10 most common change types are shown in Table 5. A complete list can be found in the Supplementary Information Table S4.

For more than a quarter of the time, there is no change of locale type for the new institutions that professors moved to. The most popular locale change is from large cities to midsize cities, followed by from midsize cities to large cities. Moves between large cities and suburbs and between small cities and large cities are also popular choices. The movement pattern for female professors is quantitatively similar to that of male professors. To get a clearer picture of the relationship between levels of institution research intensity and levels of urbanization, we kept R1 and R2 designations and merged all other Carnegie Class types into Other Class while merging three city types into City and merging all other local types as Other Local. In Supplementary Information Table S5, we separately report the move types based on institution research intensity and locals. When professors move from less research-intensive institutions to more research-intensive institutions (Other Class-R1), 9% of the moves are from urban to nonurban regions (City-Other Local) and 27% of the moves are from nonurban to urban regions. Conversely, when professors move from more research-intensive institutions to less research-intensive institutions (R1-Other Class), 22% of the moves are from urban to nonurban regions (City-Other Local) and only 12% of the moves are from nonurban to urban regions.

Table 5. Percentage of affiliations' locale change before and after academic moves for female and male professors (top 10 based on percentage of change)

Locale change	F	M	Total
No change	493 (27.2%)	1,163 (28.3%)	1,657 (27.9%)
City Large to City Midsize	146 (8.0%)	321 (7.8%)	469 (7.9%)
City Midsize to City Large	113 (6.2%)	316 (7.7%)	431 (7.3%)
City Large to Suburb	111 (6.1%)	239 (5.8%)	351 (5.9%)
Suburb to City Large	111 (6.1%)	227 (5.5%)	339 (5.7%)
City Small to City Large	103 (5.7%)	225 (5.5%)	329 (5.5%)
City Large to City Small	99 (5.5%)	212 (5.2%)	312 (5.3%)
City Small to City Midsize	83 (4.6%)	156 (3.8%)	239 (4.0%)
City Midsize to City Small	70 (3.9%)	146 (3.6%)	217 (3.7%)
Suburb to City Midsize	57 (3.1%)	131 (3.2%)	188 (3.2%)

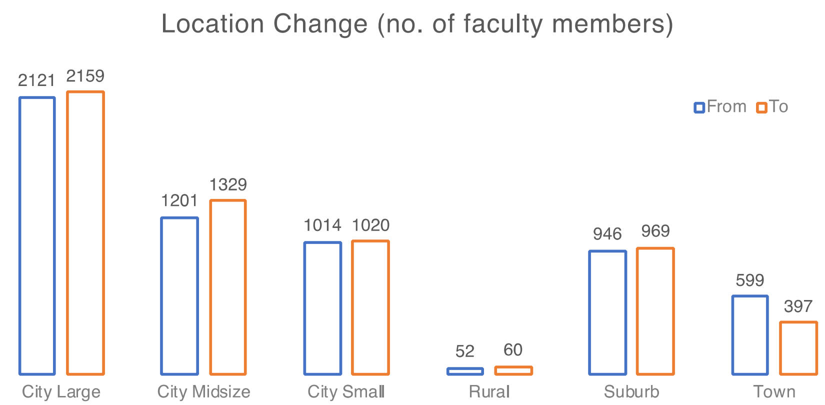

Figure 4. Number of faculty members before and after academic moves for six institution location types.

We show the change of institution locales before and after moving (Figure 4) and the pairwise moves between institutions of different location types (Figure 5).

Figure 4 shows that all three types of cities (large, midsize, and small) are popular destinations for professors. All three city sizes show increases in the number of professors who moved to these locales, whereas professors tend to move away from town-based institutions.

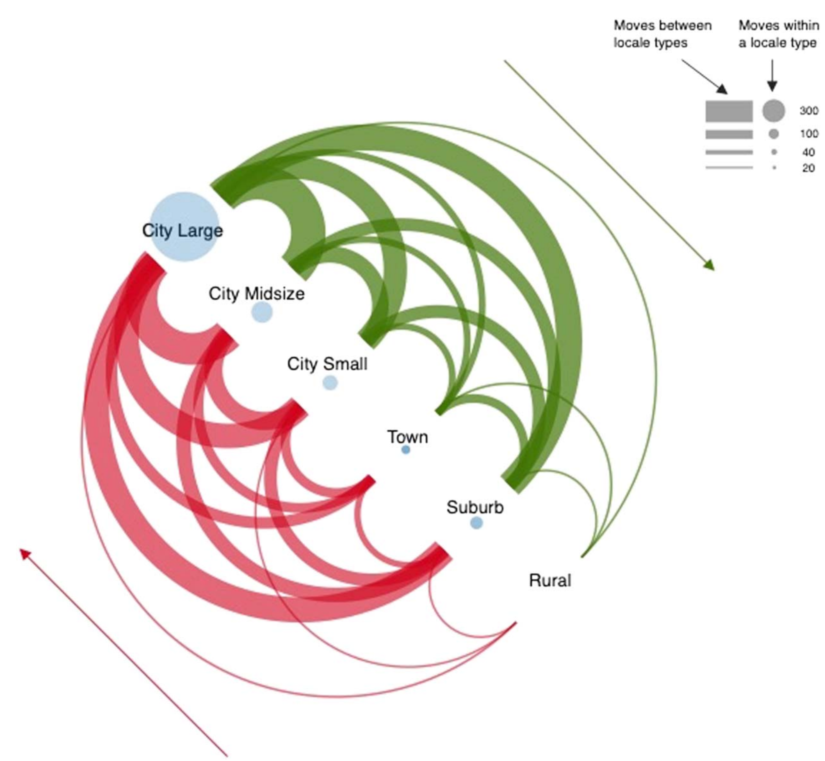

Figure 5. An illustration of pairwise moves between institutions of different location types.

Table 6. Percentage of affiliations' region change before and after academic moves for female and male professors (top 10 based on percentage of change)

Region change	F	M	Total
No change	593 (32.7%)	1,136 (27.6%)	1,731 (29.2%)
Mid East–Southeast	52 (2.9%)	150 (3.7%)	202 (3.4%)
Great Lakes–Southeast	60 (3.3%)	141 (3.4%)	201 (3.4%)
Southeast–Mid East	56 (3.1%)	131 (3.2%)	188 (3.2%)
Southeast–Great Lakes	52 (2.9%)	129 (3.1%)	181 (3.1%)
Southeast–Southwest	50 (2.8%)	112 (2.7%)	162 (2.7%)
Southwest–Southeast	29 (1.6%)	113 (2.8%)	142 (2.4%)
Mid East–Great Lakes	43 (2.4%)	96 (2.3%)	140 (2.4%)
Great Lakes–Mid East	48 (2.6%)	82 (2.0%)	131 (2.2%)
Southeast–Plains	44 (2.4%)	81 (2.0%)	125 (2.1%)

Note: New England: CT ME MA NH RI VT; Mid East: DE DC MD NJ NY PA; Great Lakes: IL IN MI OH WI; Plains: IA KS MN MO NE ND SD; Southeast: AL AR FL GA KY LA MS NC SC TN VA WV; Southwest: AZ NM OK TX; Rocky Mountains: CO ID MT UT WY; Far West: AK CA HI NV OR WA; and Outlying areas: AS FM GU MH MP PR PW VI.

A visual inspection of the arcs in Figure 5 shows that there are more moves from institutions in towns to institutions in suburbs and cities of different sizes than moves from city and suburban institutions to town institutions. The results from Figures 4 and 5 support our second hypothesis.

CCIHE classifies all U.S. states into 10 groups. The classification can be seen in the note of Table 6. We examine the changes in affiliation regions and show the top 10 most common change types.

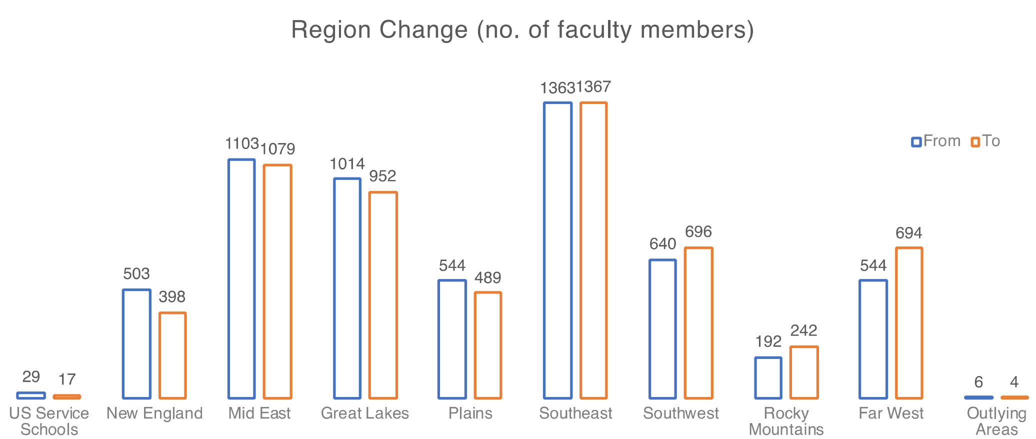

Figure 6. Number of faculty members before and after academic moves for 10 institution region types.

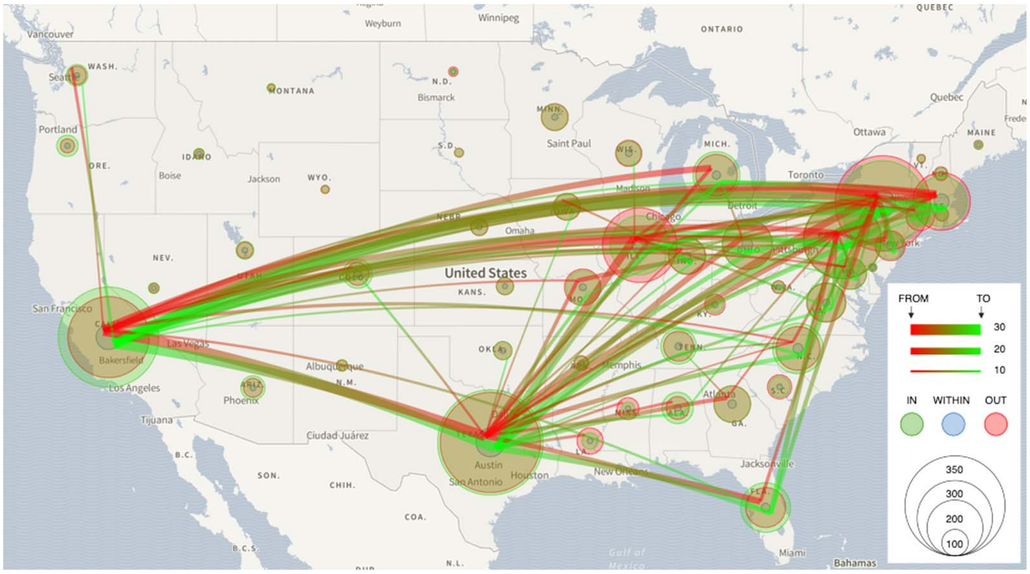

Figure 7. Map that shows the change of number of faculty for 48 U.S. continental states.[2]

One key finding from Table 6 is that female professors are less likely to move from their existing region when moving to a new institution (33% stayed in the same region vs. 28% for male professors). This result supports our fourth hypothesis. The Southeast region experienced high levels of effluxes (to Mid East, Great Lakes, Southwest, and Plains) and influxes of professors (from Mid East, Great Lakes, and Southwest).

We show the change of institution regions before and after moving (Figure 6). Regions that gained professors include Southwest, Rocky Mountains, and Far West whereas institutions in New England, Great Lakes, and Plains lost professors. The Mid East and Southeast experienced slight changes and the other two regions (U.S. Service Schools and Outlying Areas) reported low numbers.

We report the state-level academic move in Supplementary Information Table S6. The top five states with the highest exodus of professors are North Dakota (−65%), Mississippi (−53%), Louisiana (−46%), Alaska (−44%), Wyoming (−41%). The top five states/territories with the highest influx of professors are Montana (80%), Oregon (78%), Washington, DC (49%), Alabama (48%), and Arizona (37%). The top five states with the highest number of professors postmove are Texas (499), California (474), New York (400), Pennsylvania (367), and Illinois (270).

We visualize the changing numbers of faculty for the 48 U.S. continental states in Figure 7. Arcs in the maps represent the faculty moves between two states, with origination colored red and destination colored green. The width of an arc represents the number of faculty members moving from one state to another. Only moves with at least 10 faculty members are shown in this visualization. The sizes of red, blue, and green circles represent the number of faculty members moving out of, within, or into a state respectively. Using the U.S. census regions as

[2] An interactive and complete visualization can be accessed by http://jiangenhe.com/facutly_mobility/.

Table 7. Percentage of affiliations' minority serving status before and after academic moves for female and male professors

Minority serving institutions (MSI)	F	M	Total
Non-MSI to non-MSI	1,479 (81.4%)	3,364 (81.8%)	4,852 (81.7%)
Non-MSI to MSI	159 (8.8%)	386 (9.4%)	547 (9.2%)
MSI to non-MSI	137 (7.6%)	310 (7.5%)	447 (7.5%)
MSI to MSI	41 (2.3%)	51 (1.2%)	92 (1.6%)

a reference, except for Wyoming, all other states in the West region gained faculty. With the exceptions of Michigan and Ohio in the Midwest and Pennsylvania and Delaware in the Northeast, all other states in the two regions lost faculty. States in the South region exhibit diverse patterns, with Texas, Tennessee, North Carolina, Alabama, and Florida gaining faculty as others in this region lost faculty. Overall, the west and south witnessed an influx of professors and the north and east of the United States witnessed an efflux of professors.

4.3. Institution Types and Academic Moves

Using CCIHE's classification of minority serving institutions (MSI), we first measure the percentage of professors employed in MSI. Before moving, 7% of professors in the data set were employed in MSI and 9% after moving. There is a slight decrease of female professors in MSI, from 33% to 31%; however, both numbers are higher than the percentage of female professors for all institution types (30%). Table 7 shows the movement between MSI and non-MSI.

The majority of moves are within non-MSI (81%). Male professors are slightly more likely to move from a non-MSI to an MSI (9.4% for men vs. 8.8% for women) and female professors are more likely to move from one MSI to another MSI (2.3% for women vs. 1.2% for men).

Lastly, we report results on academic moves between public and private institutions (Table 8).

About half of the moves are within public institutions (51% for women vs. 49% for men). There is a decrease of both female and male professors in private institutions, from 33% to 29% for female professors and from 34% to 31% for male professors. The results suggest that female professors are slightly more likely to be employed in a public institution than male professors, both before and after moving.

Table 8. Percentage of affiliations' funding type change before and after academic moves for female and male professors

Institution type	F	M	Total
Public to public	930 (51.2%)	2,014 (50.0%)	2,947 (49.6%)
Private to public	343 (18.9%)	829 (20.2%)	1,175 (19.8%)
Public to private	282 (15.5%)	692 (16.8%)	976 (16.4%)
Private to private	251 (13.8%)	564 (13.7%)	818 (13.8%)

Note: 10 moves by female professors and 12 moves by male professors involve a for-profit private institution as the move origin or destination. These moves are not tabulated in Table 8.

5. DISCUSSION AND CONCLUSIONS

This paper used two open science data sources (ORCID and CCIHE) and identified 5,938 mobile tenure-track and tenured professors in the United States. Using the Carnegie Classification and professor profiles, we revealed patterns of academic mobility in the United States from the aspects of institution types, locations, regions, funding mechanisms, and professors' genders. We found that professors tended to move to institutions with higher research intensity such as those with a R1 or R2 designation in the Carnegie Classification. They are also more likely to move to institutions located in cities from those located in towns or rural areas. The one professor-level attribute showed that female professors tend to move within the same geographic region at a higher rate than male professors, likely a result of them preferring moves that are less disruptive to their social networks. This paper also found that female professors are less likely than their male colleagues to retain their rank or get promotion when they move from a less research-intensive institution to a more research-intensive one.

Future research will benefit from measuring the productivity and impact of professors before and after moving. We plan to link professors' ORCID profiles with the Web of Science data to obtain publication and citation data. The data will also be used in regression models to establish premove baselines and quantify the effect of academic moves on postmove productivity and impact.

AUTHOR CONTRIBUTIONS

Erija Yan: Conceptualization, Methodology, Project administration, Visualization, Writing—original draft, Writing—review and editing. Yongjun Zhu: Methodology, Writing—original draft, Writing—review and editing. Jiangen He: Visualization, Writing—original draft, Writing—review and editing.

COMPETING INTERESTS

The authors have no competing interests.

FUNDING INFORMATION

No funding has been received for this research.

DATA AVAILABILITY

The data used in this paper is freely assessable via figshare at https://doi.org/10.6084/m9.figshare.12642623.v1.

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