CRA
Computing Research Association

# An In-Depth Examination of Data and Trends Regarding Women in Computing

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Final Report

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## Introduction

It has long been the case, and widely known, that women comprise a disproportionally low fraction of the students in post-secondary academic computing programs. But look more closely at the problem, and there are many things that are not known about women's representation. Are there differences among the different disciplines within the computing field? Are there differences based on the type of institution in which the program is located? Are there identifiable points in the post-secondary academic pipeline where the relative participation of women declines? Has there been any growth in the fraction of women in academic positions, where they can serve as role models to the next generation of students? Is there, in fact, any relationship between the women on faculty in post-secondary academic computing departments and the enrollment or degree patterns in these departments?

Answers to questions such as these can help us understand better the factors that may be influencing women's choices. They may help us to identify more targeted future studies and perhaps suggest new approaches that would help increase the recruitment and retention of women in computing.

The purpose of this project is to conduct an in-depth review and re-analysis of available data from key national surveys over the past two decades, to gain deeper understanding of insight into the representation of women in computing. The past two decades encompass the dot-com boom period of the mid to late 90s, the dot-com crash of 2000-2001 and the ensuing (albeit temporary) job shortage in computing, and the emergence of many new programs and some fledgling new areas within the computing field that may attract women differentially from other, more established areas.

## Data Sources

Our investigation uses data from three sources: the annual Computing Research Association (CRA) Taulbee Survey, the Integrated Postsecondary Education Data System (IPEDS), and the National Science Foundation's Survey of Earned Doctorates (SED).

The CRA Taulbee Survey is sent to all doctoral-granting departments of computer science, computer engineering, and information in the United States and Canada. In the 2014 survey, the response rate for Computer Science programs was 76% and the overall response rate was 68% (Zweben & Bizot, 2015). Of interest to our investigation, the survey collects data from these institutions about degree production and enrollment at all degree levels, about postgraduation plans of doctoral recipients, and about faculty demographics and recruitment.

IPEDS provides comprehensive data about degrees granted at postsecondary institutions. The data is available through the National Science Foundation via National Center for Science and Engineering Statistics reports such as "Women, Minorities, and Persons with Disabilities in Science and Engineering: 2015" (National Center for Science and Engineering Statistics, 2015) and through an interactive WebCASPAR interface (WebCASPAR). Because all postsecondary institutions that grant federal financial aid are required to report to IPEDS, this coverage is nearly universal. IPEDS includes data on all postsecondary degree and certificate levels, but for purposes of this study we considered only bachelor's, master's, and doctoral data.

The SED is sent each fall to everyone who received a research doctorate from an accredited U.S. institution in the previous academic year. It asks about the respondent's educational background, demographics, and postgraduation plans. In 2013, 92% of doctoral recipients completed the survey.

Two other data sources were envisioned when we proposed this investigation. These were the new ACM survey of non-doctoral programs in computing (NDC), and the Higher Education Research Institute's Freshman Survey (HERI).

The NDC survey is similar in nature to the Taulbee Survey, but has published only two years of data so far, and the first year's data was from relatively few institutions (Prey, Timanovsky, Tims, & Zweben, 2014). We will comment as appropriate on what the NDC has revealed relative to the variables of interest to our study, but we did not do any analysis using the NDC data since there is insufficient data available to date.

The Higher Education Research Institute at UCLA conducts The Freshman Survey, an annual survey of incoming first year students about their high school preparation, family background, intended major, intended career, and highest intended degree. Our request for the data of interest from the HERI was denied, on the grounds that our research plans were too similar to data requested during the past twelve months from another research project (not either of the authors). Thus, we were unable to perform some of the investigations originally proposed. A report using this data was presented at AERA in April 2015 (Sax, et al., 2015) and discusses, among other things, the trends and gender differences in intent to major in computer science among first-year students.

## Prior Research

Studies that have reported data on women in computing/IT tend to do so either at a highly aggregated level or at a single point in time, or consider a small population of institutions to address a relatively narrow question of interest to the researchers. For example, using data from the National Center for Education Statistics (NCES), Camp notes that the proportion of information and communications technology degrees going to women decreased during the period from the mid-80s to the late 2000s, and cites the low proportion of women receiving undergraduate and graduate degrees in 2008-09 (Camp T. , 2012). In an earlier study also using data from NCES, Camp looked at a subset of universities that granted graduate degrees in CS, for which it could be determined if the location of the CS program was in Engineering or not, and determined that, for the two-year period 1991-93, a smaller percentage (18-26% smaller) of women received CS bachelor's or master's degrees if the department was within the engineering area of its campus than if it was not within the engineering area of the campus (Camp, 2002). Becerra-Fernandez, et al, studied 23 AACSB-accredited business schools, for the period 2003-4 through 2006-7. They found that these schools had a decline from 31 percent to 21 percent in the percentage of bachelor's degrees in computer/management information systems that were received by women, while the percentage of master's degrees in this field that were received by women held steady at 25 percent (Becerra-Fernandez, Elam, & Clemmons, 2010).

Richards studied NCES data from 92 liberal arts institutions during the period 1994-5 through 2004-5, and discovered that, at a given institution, the percentage of CS bachelor's degrees received by women during this period varied sufficiently that one could not identify schools that consistently graduated a relatively high proportion of women (Richards, 2009). Moskal reported that the Survey of Earned Doctorates showed that, during the decade from 1990-2000, women in the computer sciences spent longer in graduate school than did men, and ended up going to academic positions to a greater extent than did men, and to a greater extent than they went to industry positions (Moskal, 2002).

The National Center for Women in Information Technology (NCWIT) produces a periodic report called The NCWIT Scorecard: A Report on the Status of Women in Information Technology) which summarizes data on women's participation in a number of areas (National Center for Women & Information Technology, 2014).

The authors also have investigated certain elements of these questions. The authors produce an annual report of the results of the Taulbee survey, most recently (Zweben & Bizot, 2015). However, the focus of these reports is on the one-year data, with some commentary about differences from the previous year but little if any longer-term trend analysis. The ACM now conducts an annual survey similar to the Taulbee Survey for non-doctoral-granting departments of computing in the United States (Prey, Timanovsky, Tims, & Zweben, 2014). But, like the report of the Taulbee Survey, the NDC report focuses on one-year data and, since it only has been in existence for two years, has had no opportunity to do any interesting trend analysis. Bizot compared computing bachelor's and doctoral degree data from the Taulbee Survey and IPEDS, and also compared doctoral employment data from the Taulbee Survey and the SED (Bizot, 2012).

These studies individually address certain of the questions we posed, for certain groups of institutions, at different points in time. To our knowledge, there is no compendium of such results, particularly over the same time period.

# Identification of Disciplines, Institutional Characteristics, and Individual Characteristics

## Computing Disciplines

One of the key elements of our project was to determine differences, if any, in representation of women among the various major disciplines within the computing field. Many previous studies have either studied computer science alone, or used the NSF detailed field designation of computer science ("Academic Discipline: Detailed: Computer Science"), which aggregates data across several disciplines. Thus, one of our important tasks was to identify those data elements that should be associated with the different disciplines. The computing professional societies have defined five areas of interest and have issued curriculum recommendations for these areas (The Joint Task Force for Computing Curricula, 2005). They are computer science (CS), computer engineering (CE), software engineering (SE), information systems (IS) and information technology (IT). Accreditation criteria have been defined for bachelor's programs in each of these five areas. These five areas also are used to categorize programs in the ACM NDC survey.

IPEDS data provides the most detailed look at subdisciplines. Institutions report degree attainment data by Classification of Instructional Program (CIP) code, which is a U.S. Department of Education taxonomic scheme that supports the accurate tracking and reporting of fields of study and program completions activity across postsecondary programs (National Center for Educational Statistics, 2015). However, multiple CIP codes are associated with any given computing area, and not all of them are within the broad area entitled "Computer and Information Sciences and Support Services". For example, there are relevant CIP codes in the areas of engineering, business, and multidisciplinary studies. The aggregation under the detailed field designation "Academic Discipline: Detailed: Computer Science" includes all CIP codes in the "Computer and Information Sciences and Support Services" area (11.xxxx) except for 11.06 (Data Entry). Not all of the 11.xxxx codes comprise what we typically mean by "computer science", although all of those (and more) are what we consider "computing".

We examined all of the CIP codes in existence during the period from 1990 to the present. It should be noted that there have been changes in these codes over time, with several new codes added and others deleted and/or merged. Each code has a description of its intended curricular focus. We used these and the name associated with the code to determine candidates for codes that fall within computing, including all codes in 11.xxxx but also others outside of area 11.

We then looked more carefully at each of the selected codes to identify which computing discipline should be associated with the code. To assist us in this classification exercise, we frequently generated the set of institutions that identified graduates of programs with a particular code, and examined a sample of these institutions' websites to learn more about the relevant program from that institution. From this information, we then classified the code into one of several computing areas. Initially, we classified the code into the five areas CS, CE, SE, IS, IT or "none of these". We used our understanding of these areas as described in (The Joint Task Force for Computing Curricula, 2005) as the basis for this determination. In some cases we determined that the programs reporting a particular CIP code did not really appear to be computing programs at all but instead were programs in another discipline with little if any computing requirement, or codes that were used for certificate programs but not for baccalaureate or post-baccalaureate programs. In these cases we eliminated the code as a candidate for further analysis. For those codes that were not eliminated, but were not categorized into the five areas, we identified three other areas for separate analysis. These were "information science" (Isci), "security" (Sec) and "interdisciplinary" (Idsc). Information science was singled out at the recommendation of colleagues from the dean's group of the Computing Research Association. Security was singled out as an area in which there currently is some active effort to identify possible program criteria for accreditation.

### *Classification of IPEDS CIP Codes into Disciplines*

Our classification of CIP codes into the various disciplines is as follows:

## Computer Science CIP Codes

| Code | Title |
|---|---|
| 11.0101 | Computer and Information Sciences, General |
| 11.0102 | Artificial Intelligence |
| 11.0199 | Computer Science, Other |
| 11.0701 | Computer Science |
| 11.9999 | Computer and Information Sciences and Support Services |

## Computer Engineering CIP Codes

| Code | Title |
|---|---|
| 14.0901 | Computer Engineering, General |
| 14.0902 | Computer Hardware Engineering |
| 14.0999 | Computer Engineering, Other |

## Software Engineering CIP Codes

| Code | Title |
|---|---|
| 14.0903 | Computer Software Engineering |

## Information Systems CIP Codes

| Code | Title |
|---|---|
| 11.0501 | Computer Systems Analysis/Analyst |
| 52.1201 | Management Information Systems, General |
| 52.1203 | Business Systems Analysis and Design |

## Information Technology CIP Codes

| Code | Title |
|---|---|
| 11.0103 | Information Technology |
| 11.0201 | Computer Programming/Programmer, General |
| 11.0202 | Computer Programming Special Applications |
| 11.0203 | Computer Programming, Vendor/Product Certification |
| 11.0299 | Computer Programming, Other |
| 11.0301 | Data Processing and Data Processing Technology/Technician |
| 11.0801 | Web Page, Digital/Multimedia and Information Resources Design |
| 11.0802 | Data Modeling/Warehousing and Database Administration |
| 11.0804 | Modeling, Virtual Environments and Simulation |
| 11.0899 | Computer Software and Media Applications, Other |
| 11.1001 | Network and System Administration/Administrator |
| 11.1002 | System, Networking, and LAN/WAN Management/Manager |

## Information Science CIP Codes

| Code | Title |
|---|---|
| 11.0401 | Information Science/Studies |

## Security CIP Codes

| Code | Title |
|---|---|
| 11.1003 | Computer and Information Systems Security / Information Assurance |

## Interdisciplinary CIP Codes

| Code | Title |
|---|---|
| 09.0702 | Digital Communication and Media/Multimedia |
| 10.0304 | Animation, Interactive Technology, Video Graphics and Special Effects |
| 11.0104 | Informatics |
| 11.0803 | Computer Graphics |
| 11.0901 | Computer Systems Networking and Telecommunications |
| 26.1103 | Bioinformatics |
| 26.1104 | Computational Biology |
| 26.1199 | Biomathematics, Bioinformatics, and Computational Biology, Other |
| 27.0303 | Computational Mathematics |
| 27.0304 | Computational and Applied Mathematics |
| 30.0801 | Mathematics and Computer Science |
| 30.1601 | Accounting and Computer Science |
| 30.3001 | Computational Science |
| 30.3101 | Human Computer Interaction |
| 50.0102 | Digital Arts |
| 51.2706 | Medical Informatics |

## CIP Codes Considered but Not Included

| Code | Title |
|---|---|
| 25.0101 | Library and Information Science |
| 52.1206 | Information Resources Management |
| 52.1207 | Knowledge Management |
| 52.1299 | Management Information Systems and Services, Other |

Because new codes were introduced over time, some of the codes that existed both before and after a new code was introduced may well aggregate data from multiple disciplines prior to the new disciplinary codes being introduced. We note this as a source of error for which we cannot correct given the level of specificity of the data.

For example, prior to 1995 the code 11.9999 likely included degree production in what we refer to as Information Science in addition to degree production in Computer Science. The more recent data likely has less confounding in this respect than does the data from earlier years.

Table 1 illustrates the proportion of computing degrees produced by each discipline during the most recent year (2013). It also shows the discipline's proportion of computing degrees granted to women in that year. The table shows, for example, that CS accounts for about 1/3 of all computing bachelor's degrees, while it accounts for only about ¼ of computing bachelor's degrees granted to women.

Table 1. Share of Computing Degrees by Discipline in 2013 (Source: IPEDS)

| | Bachelor's | | Master's | | Doctoral | |
|---|---|---|---|---|---|---|
| | % of Degrees M+F | % of Degrees F Only | % of Degrees M+F | % of Degrees F Only | % of Degrees M+F | % of Degrees F Only |
| CS | 33.1% | 24.8% | 38.4% | 32.2% | 62.1% | 55.5% |
| CE | 6.5% | 3.2% | 6.1% | 4.1% | 14.0% | 10.4% |
| SE | 0.8% | 0.3% | 3.5% | 3.2% | 0.2% | 0.0% |
| IS | 13.4% | 17.5% | 11.9% | 12.9% | 1.8% | 2.0% |
| IT | 19.4% | 21.1% | 12.7% | 13.9% | 3.1% | 3.7% |
| Isci | 8.2% | 9.1% | 13.2% | 16.9% | 6.0% | 11.2% |
| Sec | 5.7% | 4.3% | 4.9% | 3.7% | 0.7% | 0.6% |
| Idsc | 12.9% | 19.7% | 9.4% | 13.2% | 12.3% | 16.5% |
| Total | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| # Deg | 71,289 | 13,978 | 31,098 | 8,731 | 2,490 | 490 |

### *Disciplines in Taulbee Survey Data*

For the Taulbee Survey data, departments are asked to categorize their programs as either in CS, CE, or information (I). These categories do not map cleanly onto the five-discipline breakdown from the professional societies nor onto the eight areas from the CIP code analysis. The information category, which was added to the Taulbee in 2008, may include IS and IT programs as well as computing programs that are not clearly in IS or IT, and at different institutions software engineering may be included with CS or with CE.

For doctoral degrees, Taulbee data also categorizes each degree into one of 19 specialty areas. These areas do not map cleanly to the other discipline breakdowns.

### *Disciplines in SED Data*

In the Survey of Earned Doctorates, we identified the following disciplines as relevant to computing (SED codes are in parenthesis): Computer Science (400), Computer Engineering (321), Information Science & Systems (410), Robotics (415), and Computer & Information Systems, Other (419). Respondents are asked to select the appropriate discipline from among these choices for both their field of doctorate and for their dissertation. Not all categorize their dissertation as in the same discipline as their program field. We requested data on respondents whose program field was in the areas above, but some of their dissertations are categorized as outside of areas we would consider computing (e.g. categorized as education, business, or life sciences). Ninety-two percent of those in the field of CS categorized their dissertation discipline as CS, while only 85% of those in the field of Information Science & Systems categorized their dissertation in the same discipline, presumably reflecting the applicability of Information Systems to many areas. When we report data from the SED, we are reporting based on the field of doctorate as selected by the respondents. The five SED choices do not map cleanly into the five professional society areas CS, CE, IS, IT and SE, It would be possible to identify as Interdisciplinary those individuals for whom the field of dissertation is different from the field of doctorate, but even so, the eight areas we identified from the CIP code analysis would not cleanly roll up into the SED areas. In a few cases we use the Computer Science SED results in order to compare to Computer Science from Taulbee or IPEDS data, but in most cases, we use all disciplines together in the SED analyses.

## Institutional Characteristics

Two key types of institutional characteristics of interest to our study are those of "private" versus "public" and, for baccalaureate degree analyses, "research" versus "non-research". Within the "private" category, those institutions that are for-profit are of interest as distinct from those that are not-for-profit. Conventional wisdom is that research institutions provide more access to cutting-edge science but non-research institutions, which tend to be smaller, provide a more supportive environment, which may be especially significant for members of underrepresented groups (Wilson, 2006).

In the Taulbee Survey, all institutions are of type "research" and none of the institutions are for-profit. Thus, we cannot do any analysis for Taulbee data based on the research vs non-research institutional characteristic. The Taulbee Survey reports only have separated data based on private vs public status during the last three years, so no trend analysis of the Taulbee data was performed based on the public/private institutional characteristic. Though the Taulbee database also includes, for many respondents, the college or school in which the department resides (these colleges are categorized as Arts & Sciences, Computing and Information, Engineering, and Science), the database does not record the location of the *program* offered by these departments, which can be different from the location of the department. Therefore, we did not analyze Taulbee data based on the location within the institution. Finally, the Taulbee data allows us to investigate the percent of women faculty as an institutional characteristic that may affect the percent of women students.

The IPEDS database clearly disaggregates the data into public vs private, and also clearly disaggregates the private institutions into for-profit and not-for-profit. It further classifies institutions using Carnegie classifications (Carnegie Commission on Higher Education) such as "Associates Colleges", "Baccalaureate Colleges", "Masters Colleges and Universities", "Doctoral/Research Universities", "Research Universities" (further subdivided into High and Very High research activity), "Special Focus Institutions" and "Tribal Colleges". For the purposes of our investigation, we defined "research" institutions as those classified under "Doctoral/Research Universities", "Research Universities-High Research Activity" and "Research Universities-Very High Research Activity". All other institutions were classified as "non-research".

The SED data contains the public/private status and Carnegie classification of the respondent's doctoral institution and baccalaureate institution for those that received their baccalaureate inside the U.S.; baccalaureate institutions outside the U.S. are categorized as "foreign." For the US schools, we categorized the baccalaureate institutions as "public" and "private," "research" and "non-research" in the same way we categorized IPEDS records. We did not do any analyses based on the public/private characteristics of the respondent's doctoral institution (there are too few doctorates in private for-profits to do any analysis using that set of institutions), but we did separate the public, private for-profits, and private not-for-profits when considering the baccalaureate institutions.   For baccalaureates from outside the U.S., the country or region of baccalaureate was coded for locations that were the baccalaureate origin of 5% or more of PhDs over the full 1990-2013 time span. Those locations were India, China, South Korea, and the Middle East.

## Individual Characteristics

Along with institutional characteristics, we were interested in differences due to individual characteristics.  For example, what differences were present between majority women and minority women?  What differences in women's participation exist for non-resident women as compared with resident majority and/or resident minority women?

The IPEDS, Taulbee, and the SED all disaggregate data into various ethnicity categories by gender.  They use the Department of Education ethnicity categories which include "American Indian or Alaska Native," "Asian or Pacific Islander" (in SED since 2001, this is separated into "Asian" and "Native Hawaiian or Pacific Islander"), "Black, Non-Hispanic" or "Black/African American," "Hispanic" (subdivided in SED among "Puerto Rican," "Mexican/Chicano," "Cuban," and "Other Hispanic"), "White, Non-Hispanic," "Temporary Resident," and "Other/Unknown Races & Ethnicities."  Taulbee and the SED also include a Multiracial category. For our analysis, we grouped the ethnicities into three categories:  Majority, Minority, and Non-resident.  We classified as Minority those ethnicities traditionally underrepresented in computing, including "American Indian or Alaska Native,""Black, Non-Hispanic," and "Hispanic." We classified "Asian or Pacific Islander" and "White Non-Hispanic" as Majority.  The classification "Asian and Pacific Islander" includes sub-groups whose origin is from areas of Asia that clearly are well-represented in computing, as well as other sub-groups whose origin is from areas that may not be well-represented in computing (iCount, 2013).  However, with the exception of SED since 2001, our sources do not collect data at a level of detail to permit this distinction, and Asian Americans as a broad group are well-represented in computing. When using the SED data since 2001, we classified "Asian" as majority and "Native Hawaiian or Pacific Islander" as minority. We classified "Temporary Resident" as Non-resident and omitted data from the categories "Multiracial" and "Other/Unknown Races & Ethnicities" when analyzing by individual characteristics. Table 2 shows the proportion of computing degrees awarded in 2013 within each ethnicity category at each degree level.

Table 2. Share of Computing Degrees by Ethnicity in 2013 (Source: IPEDS)

| | Bachelor's | | Master's | | Doctoral | |
|---|---|---|---|---|---|---|
| | % of Degrees M+F | % of Degrees F Only | % of Degrees M+F | % of Degrees F Only | % of Degrees M+F | % of Degrees F Only |
| Temporary Resident | 4.8% | 5.4% | 40.5% | 42.3% | 52.2% | 48.2% |
| Black, Non-Hispanic | 10.1% | 14.6% | 8.5% | 12.1% | 3.1% | 5.5% |
| Amer Indian/Alaskan | 0.5% | 0.7% | 0.2% | 0.3% | 0.0% | 0.0% |
| Asian/Pac Islander | 9.1% | 9.7% | 8.4% | 9.2% | 7.2% | 9.2% |
| Hispanic | 9.9% | 11.1% | 4.1% | 3.7% | 2.2% | 2.4% |
| White, Non-Hispanic | 56.3% | 47.9% | 30.0% | 23.7% | 29.2% | 25.7% |
| Other/Unknown | 9.3% | 10.6% | 8.2% | 8.7% | 6.0% | 9.0% |
| Total | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| # Degrees | 71,289 | 13,978 | 31,098 | 8,731 | 2,490 | 490 |

## Identification of Key Educational and Career Stages and Transition Points

We looked at the following educational and career stages and transition points:

- Degrees awarded (bachelor's, master's, and doctoral)
- The doctoral educational process (baccalaureate institutions of doctoral recipients, enrollment in doctoral programs, sources of funding for doctorate, time to doctoral degree,)
- Postgraduation plans of doctoral recipients
- Other career stages

## Degrees Awarded

CRA's niche is in computing research, and therefore our interest in students who may potentially choose research careers shaped our decisions about where to draw the boundaries of our study.  We chose to look only at bachelor's, master's, and doctoral data.  We did not consider associate or postsecondary certificates, although we recognize that two-year and other programs can provide an important pathway to baccalaureate study and certain careers in computing.

## Doctoral Education Process

The Taulbee Survey includes information on PhD enrollment.

The SED includes information on the students' doctoral career (baccalaureate institution, primary source of funding, time to degree.)

## Postgraduation Plans

The Taulbee survey includes information on the postgraduation plans of new PhD recipients as reported by their departments: those going to postdocs, to academia, and to industry; those staying in North America and those going abroad.  Taulbee also provides data about new faculty hires.

The SED includes information on the postgraduation plans (postdoctoral study vs. employment, type of employer, expected work activities, location, and salary) as reported by the degree recipient.

We used three variables in the SED to compute a postgraduation employment indicator of Postdoc, Academia, or Industry. While it would have been interesting to compare trends in academic postdocs to industry postdocs, the coding in this area has changed several times between 1990-2013 and a breakdown in that form was not available in earlier years.

The three variables we used were POSTDOC, PDOCPLAN, and PDEMPLOY.

POSTDOC: Do you intend to take a postdoc position? Yes/no (since 2004). The employment type was coded as Postdoc if this was yes.

PDOCPLAN:  Has varied over the years. The employment type was coded as Postdoc if this was 0, 1, 2, 3, or 4 (various types of postdoctoral training and study).

PDEMPLOY: Postdoctoral employer. Employment type was coded as Academia if the student was not taking a postdoc and PDEMPLOY = A, B, C, or F (U.S. 4-year institutiton, U.S. medical school, U.S. research institute with academic affiliation, and Foreign educational institution). There are also codes for community college employment and K-12 employment; these were omitted from the academia category because the groups were too small to analyze separately (90 community college and 47 K-12 over the entire time period) and because 65% of these 137 were continuing with or returning to a predoctoral employer according to their PDOCSTAT.

Employment type was coded as government for non-postdocs with PDEMPLOY = G, H, I, or J. (Foreign government, U.S. federal, U.S. state, and U.S. local)

Employment type was coded as Industry for non-postdocs with PDEMPLOY = L.

The SED variable for status of postdoctoral plans was, for our purposes, collapsed into "definite" – returning to or continuing in predoctoral employment or definite commitment made, and "not definite" including those in negotiation, still seeking, or other. For the salary analysis, we considered only those with definite plans; for analysis of postgraduation plans, we included those who were still seeking or negotiating.

## Other Career Stages

The Taulbee Survey provides information about faculty demographics at each faculty rank by gender.  Trends in this data can give indications of the general progress of women in faculty career positions, although not at the level of the individual faculty member.

A final element of career progression of computing professionals that we identified for investigation was the attainment of Fellow status within the two major computing professional societies – ACM and (the Computer Society of) the IEEE.  This information is available from the respective society web sites.

## Analysis Methods

One of the types of analysis of interest in our study involves basic trends of women's participation over time. For example, we are interested in the trends of the fraction of bachelor's degrees granted to women at public universities from 1990 to the present. To determine significant changes over time we used the Spearman rank correlation coefficient, with year and percent of women participation as the two variables whose ranks were being examined. Significant positive (increasing) trends are indicated by a significant positive correlation, and significant negative (decreasing) trends are indicated by a significant negative correlation.

A second type of analysis involves comparison of two participation variables. For example, we are interested in comparing the degrees granted to women at public vs private institutions. For such comparisons, we used the Wilcoxon Matched-Pairs Signed-Ranks Test. Each year's data about percent of women for the two variables being compared is a matched-pair for the purposes of these tests.

Nonparametric tests were used for each type of analysis to compensate for the uncertainty that the assumptions of parametric tests (such as ANOVA) were met.

## Results

We present the results by educational and career stage, as outlined in an earlier section. Accompanying charts visually illustrate the data. Depending on the degree level, institutional characteristics, individual characteristics, disciplines under study, etc., there may be insufficient data for a trend analysis to be meaningful. Thus, we present data only from those years in which a sufficient data is present to allow meaningful trend analysis.

Each result includes the data source (typically Taulbee, IPEDS or SED), the years for which the data was analyzed (based on the availability at the data source of sufficient relevant data for analysis), and the result of the analysis (significant or not significant; if significant, the lowest alpha level at which the hypothesis, of no trend or no difference between the two variables, could be rejected). Possible alpha levels are .01, .02, .05 and .10. All tests are two-tailed. Those analyses for which we had pre-conceived hypotheses when we wrote our proposal are accompanied by a statement of the hypothesis. For these analyses, the two-tailed test is very conservative; a two-tailed test significant at alpha = .10 (.02) would be significant at alpha = .05 (.01) for a one-tailed test against the pre-conceived hypothesis.

## Degrees Awarded

Data is presented for each of bachelor's, master's and doctoral degrees granted. For each degree level, we will comment on the trends and the differences among them with respect to discipline. For the computer science area, we also will compare the IPEDS data and the data from the Taulbee Survey. The Taulbee Survey also has some data about CE degrees, but there are very few CE programs that report data to this survey. For the past several years, the Taulbee Survey also collects data about "information" programs. But these programs are not easily mapped into the disciplinary areas of, for example, information systems, information technology and information science. Therefore, no analysis is performed for the CE and I data from the Taulbee Survey.

### *Overall Trends*

#### Bachelor's Degrees (hypothesis: negative trend)

Figure 1 shows the overall trend of the percentage of women receiving bachelor's degrees using IPEDS data for each discipline. Consistent with our hypothesis, most of the disciplines show a negative trend in these percentages. Only the interdisciplinary and software engineering areas show no significant trend. The software engineering area is one for which sufficient data has been around for the fewest years. The interdisciplinary area actually shows an increase in recent years, though the long term trend is not significant. The security area shows a mildly significant increasing trend (alpha = .10), and is the other area for which sufficient data has been available for a relatively short time. The other five areas (CS, CE, IS, IT, and ISci) all show negative trends significant at alpha = .01 with no evidence of recent increases.

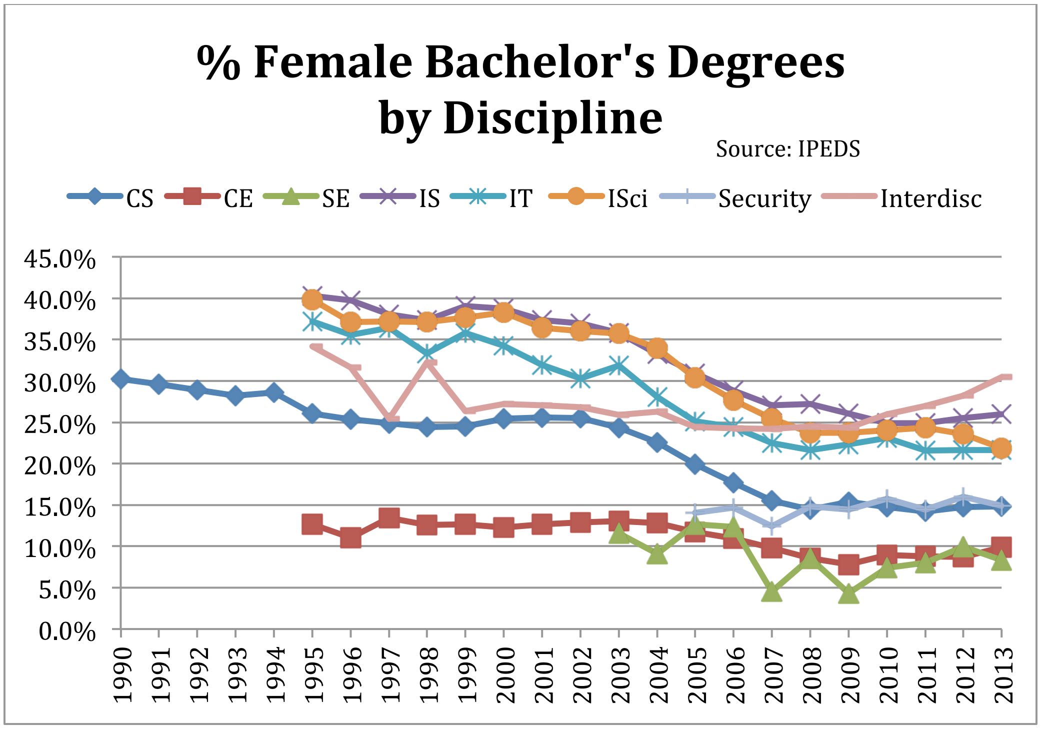


Figure 1. % Female Bachelor's Degrees by Discipline.

The graph illustrates that the different disciplines have very different percentages of women graduates. The interdisciplinary area has the highest percentage of female graduates (just over 30 percent), followed by IS at about 26 percent. ISci and IT also are over 20 percent. Those with the smallest percentage of female graduates are computer engineering and software engineering, each of which is in the 8-10 percent range in recent years. Computer science and security are at 14-15 percent in recent years.

Figure 1 also illustrates that the timing of the declines in percentages vary somewhat from one discipline to another. Starting around the millennium, the IS, IT and ISci areas began their decline, though the sharpest decline began around 2004. For areas like CS and CE, the decline began somewhat later (2003 for CS and 2005 for CE). Declines tended to last until the late 2000s no matter when they began. The representation of women among graduates in each of these disciplines appeared to be adversely affected by the changing employment climate in computing brought on when the dot-com bubble burst at the start of the millennium.

Figure 2 shows the computer science trend line from IPEDS and the corresponding trend line from the CRA Taulbee Survey. The two lines are very similar, with rank correlation of 0.98 (significant at alpha = .01) and both showing negative trends significant at alpha = .01. The IPEDS line shows greater percentages of women than does the Taulbee line. Since the Taulbee institutions all are research institutions, this suggests that the percentage of women graduating in CS from research institutions is less than that from non-research institutions. We will explore this further in the section on institutional characteristics.

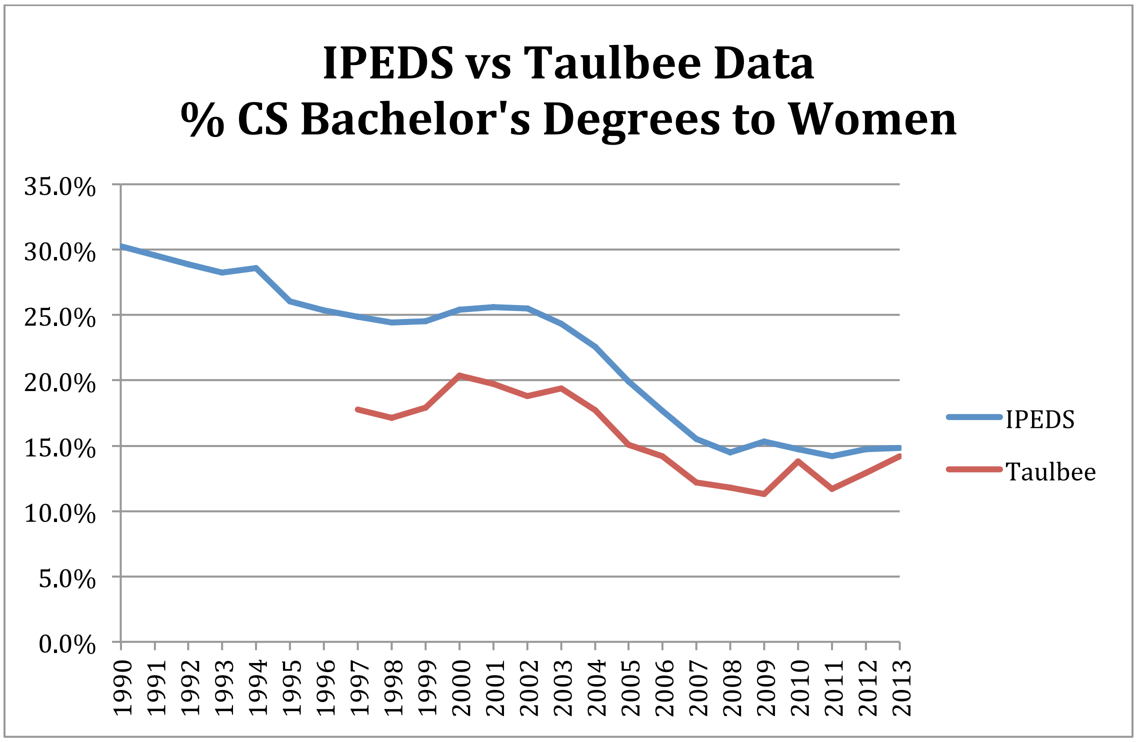


Figure 2. IPEDS vs. Taulbee Data % CS Bachelor's Degrees to Women.

We also have a data point for 2013 from the ACM NDC Survey, which showed 13.8 percent of the reported bachelor's degrees awarded to women. This is somewhat below the Taulbee Survey's figure of 14.2 percent and IPEDS' 14.8 percent.

## Master's Degrees (hypothesis: no significant trend)

Figure 3 shows the trends by discipline for the percentage of master's degrees awarded to women. There is no significant trend for most of the disciplines; there is a significant negative trend in computer science (alpha = .02), and a mildly significant negative trend in computer engineering (alpha = .10). Our hypothesis of no significant trend in the percentage of female master's graduates is largely confirmed by these data.

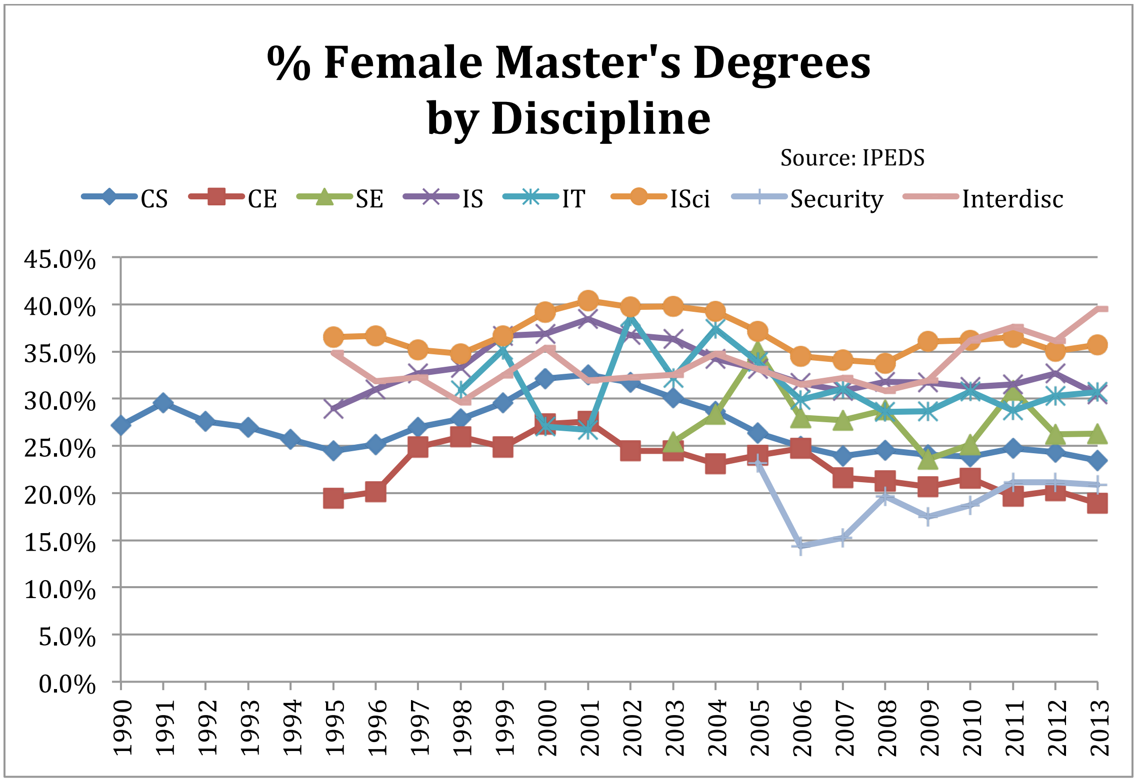


Figure 3. % Female Master's Degrees by Discipline.

Again we see a wide range in the actual percentages of degrees awarded to women from one discipline to another. Information science and interdisciplinary areas are the highest, in the 35-40 percent range recently, while computer engineering and security are the lowest, at around 20 percent in recent years. Computer science currently is at around 24-25 percent.

Note that in many of the disciplines, there was an increase in the percentage of women receiving degrees from the mid-90s through the early 2000s (i.e., largely during the dot-com boom), followed by a decline of varying lengths. For most disciplines, the percentages have leveled off in recent years, though in the interdisciplinary area there is a noticeable increase in the past four years.

Figure 4 compares the computer science master's data from IPEDS and the Taulbee Survey. The Taulbee trend line also is a negative trend, significant at alpha = .05. As was the case with the bachelor's data, the Taulbee percentages of degrees awarded are lower than the corresponding yearly percentages in the IPEDS data. The ACM NDC Survey reported that, for 2013, 28.6 percent of the master's degrees given by the reporting non-doctoral-granting computing departments went to women. This is a higher percentage than the 21.2 percent from the Taulbee Survey and 23.5 percent from the IPEDS data for that year.

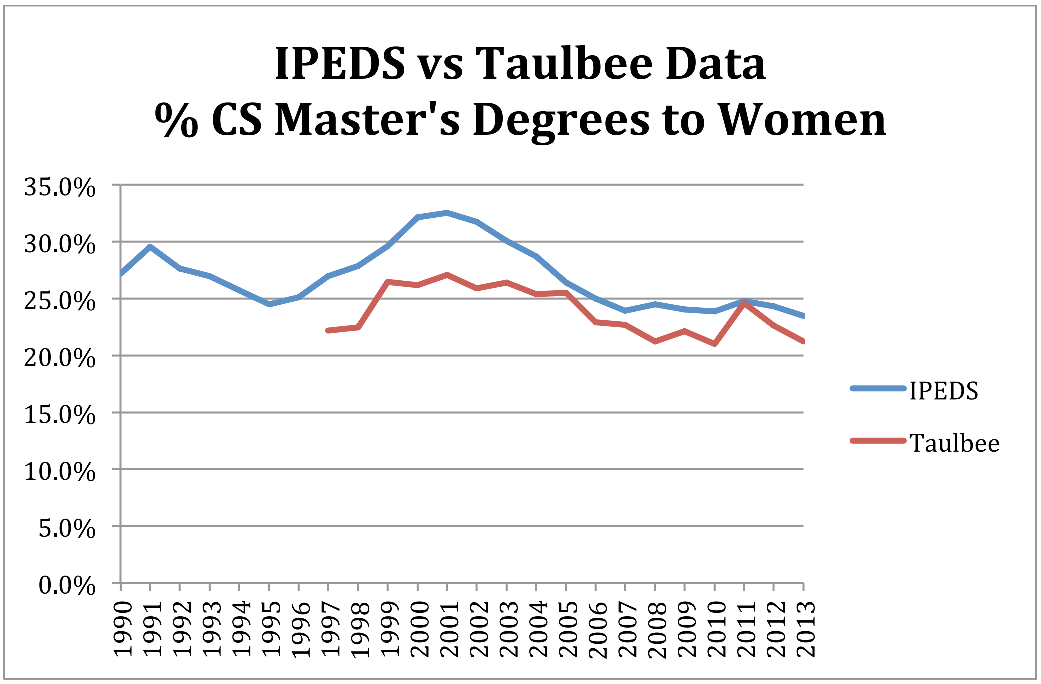


Figure 4. IPEDS vs. Taulbee Data % CS Master's Degrees to Women

Comparing Figure 1 and Figure 3 and Figures 2 and 4, we also see that, for each discipline, the recent percentage of master's degrees awarded to women is higher than the percentage of bachelor's degrees awarded to women, even after one accounts for a multi-year lag in the typical timing of receipt of a master's degree relative to the year in which the bachelor's degree was obtained. Possible explanations for this observation include 1) an increased proportion of women entering graduate programs in computing after having obtained bachelor's degrees in a non-computing field (this is difficult to do in many graduate programs), 2) an increased proportion of women entering graduate programs after having obtained their undergraduate degree abroad, and 3) a larger proportion of women as compared with men who go on to graduate programs after having obtained their bachelor's degree in computing.

## Doctoral Degrees (hypothesis: positive trend)

Sufficient data to analyze doctoral degree production trends is only available for the computer science, computer engineering, information science and interdisciplinary areas (Figure 5). The computer science and computer engineering trends are positive, consistent with our hypothesis. Computer science's positive trend is significant at alpha = .01, computer engineering's is at alpha = .02. The information science and interdisciplinary trends are not significant.

The percentages of female doctoral graduates for the CS, CE and interdisciplinary areas tend to be in between the areas respective percentages for bachelor's and master's degrees. The information science areas percentage of female doctoral graduates exceeds those from that discipline for bachelor's or master's degrees.

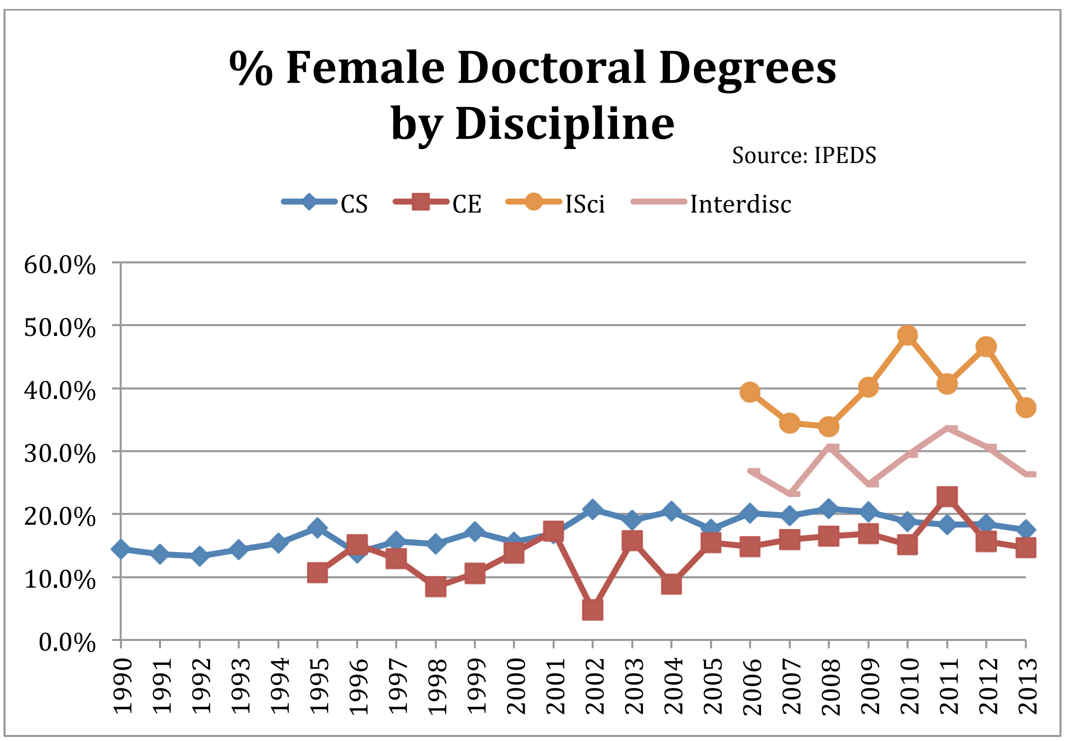


Figure 5. % Female Doctoral Degrees by Discipline.

Figure 6 compares the IPEDS, Taulbee, and SED data. As with the previous comparisons with IPEDS and Taulbee, the shapes are similar and all show increasing trends significant at alpha = .01. The Taulbee percentages again tend to be less than those for IPEDS, but since 2007 the two percentages are nearly the same.

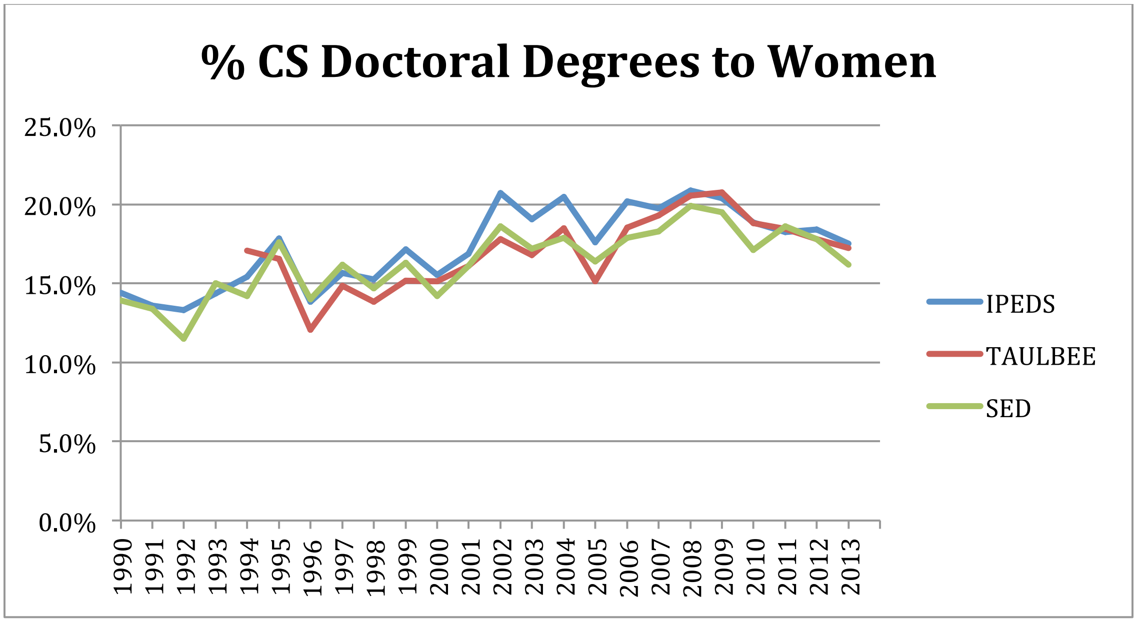


Figure 6. % CS Doctoral Degrees to Women.

## Summary of Overall Degree Trend Results

Table 3 summarizes the results of our analysis of the IPEDS data trends for each degree level and each discipline.

**Table 3. Summary of Trends by Degree Level and Discipline.**

| Degree | CS | CE | SE | IS | IT | ISci | Security | Interdisc |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| BS Overall | ↓××× | ↓××× | ↔ | ↓××× | ↓××× | ↓××× | ↑ᵻ | ↔ |
| MS Overall | ↓ ×× | ↓ᵻ | ↔ | ↔ | ↔ | ↔ | ↔ | ↔ |
| PhD Overall | ↑××× | ↑× | na | na | na | ↔ | na | ↔ |

| | | | | |
|---|---|---|---|---|
| Key: | ↑ | increasing trend | ᵻ | significance level = .10 |
| | ↓ | decreasing trend | × | significance level = .05 |
| | ↔ | no significant trend | ×× | significance level = .02 |
| | na | insufficient data for analysis | ××× | significance level = .01 |

Starting year for analyses: CS 1990; CE 1995; SE 2003; IS 1995; IT 1995 for BS and MS, 1999 for Ph.D.; Sec 2005; ISci and Idsc 1995 for BS and MS, 2006 for Ph.D.

## Summary of Taulbee Specialty Area Data

Table 4 shows, for each of the 19 specialty areas that Taulbee counts within computing, the number and percent of female PhDs within that area and the total degrees within that specialty area and the percent of degrees with a known specialty area that were granted in that area (omitting the 21% of PhDs whose specialty areas were not categorized). This includes all PhDs between 2008 (when the list of specialty areas was revised) and 2013 and is in order by the highest number (not percent) of degrees to women during that time.

These specialty areas cannot be mapped onto the eight disciplines from the IPEDS data – in particular, there is no clear "CS" group - but some comparison is possible. The highest areas of percent of women are Information Science (as with IPEDS) and Human-Computer Interaction (an interdisciplinary area, so also congruent with the

IPEDS findings in Fig 5). Hardware/Architecture and Robotics are the two areas most overlapping with Computer Engineering, and both of those have lower than average percentages of women.

Table 4. Taulbee Specialty Areas By Gender, 2008-2013.

| | Male | | Female | | Total (including gender not reported) | |
|---|---|---|---|---|---|---|
| Specialty Area | Number | % of Area | Number | % of Area | Number | Area % of degrees |
| Artificial Intelligence | 877 | 81.9% | 194 | 18.1% | 1,105 | 12.6 |
| Databases/Information Retrieval | 517 | 74.3% | 179 | 25.7% | 722 | 8.2 |
| Software Engineering | 648 | 78.8% | 174 | 21.2% | 838 | 9.5 |
| Networks | 734 | 82.8% | 152 | 17.2% | 898 | 10.2 |
| Human-Computer Interaction | 262 | 65.5% | 138 | 34.5% | 409 | 4.7 |
| Theory and Algorithms | 557 | 83.3% | 112 | 16.7% | 686 | 7.8 |
| Informatics: Biomedica/Other Science | 321 | 76.6% | 98 | 23.4% | 440 | 5.0 |
| Information Science | 110 | 57.3% | 82 | 42.7% | 192 | 2.2 |
| Graphics/Visualization | 508 | 86.2% | 81 | 13.8% | 604 | 6.9 |
| Hardware/Architecture | 401 | 85.5% | 68 | 14.5% | 480 | 5.5 |
| Information Assurance/Security | 365 | 85.1% | 64 | 14.9% | 436 | 5.0 |
| Information Systems | 159 | 73.3% | 58 | 26.7% | 222 | 2.5 |
| High-Performance Computing | 194 | 78.9% | 52 | 21.1% | 256 | 2.9 |
| Programming Languages/Compilers | 302 | 85.8% | 50 | 14.2% | 360 | 4.1 |
| Operating Systems | 292 | 85.6% | 49 | 14.4% | 345 | 3.9 |
| Robotics/Vision | 346 | 87.6% | 49 | 12.4% | 407 | 4.6 |
| Scientific/Numerical Computing | 133 | 78.7% | 36 | 21.3% | 177 | 2.0 |
| Social Computing/Social Informatics | 94 | 73.4% | 34 | 26.6% | 131 | 1.5 |
| Computer-Supported Cooperative Work | 44 | 71.0% | 18 | 29.0% | 69 | 0.8 |
| Total | 6,864 | 80.3% | 1,688 | 19.7% | 8,777 | |

### *Institutional Characteristics*

For each disciplinary area, we disaggregated the IPEDS degree production data according to whether the institution granting the degree was public, private not-for-profit, or private for-profit. Where there was sufficient data to do so, we also examined the trends within each of the public and private not-for-profit groups according to whether or not the institution was a research institution. Our hypotheses are that a) private for-profit institutions will grant a greater percentage of degrees to women than will private not-for-profit; and b) non-research institutions will grant a greater percentage of degrees to women than will research institutions. We did not have any hypothesis relative to a comparison of public and private institutions.

Table 5. Total Bachelor's Degrees in 2013 by Institution Type and Discipline (Source: IPEDS)

| | Private FP | Private NFP | | Public | | Total |
|---|---|---|---|---|---|---|
| | | Research | Non-Research | Research | Non-Research | |
| CS | 540 | 2,968 | 4,698 | 9,588 | 6,487 | 24,281 |
| CE | 17 | 488 | 420 | 3,230 | 578 | 4,733 |
| SE | 179 | 29 | 145 | 132 | 105 | 590 |
| IS | 1,536 | 561 | 1,817 | 3,964 | 1,969 | 9,847 |
| IT | 6,967 | 808 | 2,155 | 2,194 | 2,078 | 14,202 |
| Isci | 748 | 410 | 465 | 2,056 | 2,362 | 6,041 |
| Sec | 3,050 | 143 | 462 | 68 | 473 | 4,196 |
| Idsc | 3,321 | 467 | 2,285 | 2,460 | 891 | 9,424 |
| | | | | | | |
| Total | 16,358 | 5,874 | 12,447 | 23,692 | 14,943 | 73,314 |

Table 5 shows the total number of bachelor's degrees granted in 2013 to men and women combined, for each discipline and type of institution. Private for-profits grant a large fraction of the degrees in IT and in Security, but a very small fraction of CS and CE degrees. Among private not-for-profits, non-research institutions grant more degrees than do research institutions except in CE. Among publics, research institutions grant more degrees than do non-research institutions except in Isci and Security.

## Computer Science

In computer science, as shown in Figure 7, the percentage of women receiving bachelor's degrees at private for-profit institutions is significantly higher than the corresponding percentage receiving bachelor's degrees at private not-for-profit institutions, which in turn is significantly higher than the percentage receiving bachelor's degrees at public institutions (all significance levels at alpha = .01). This ordering is present in nearly every individual year between 1990 and 2013. As shown in Figure 8, the percentage of women receiving bachelor's degrees from non-research universities is significantly higher than the corresponding percentage receiving bachelor's degrees from research universities, and this relationship holds at both public and private not-for-profit institutions (alpha = .01 in both cases). The relationship between research and non-research universities confirms the feature we observed in Figure 2, where the percentages from Taulbee institutions were less than those for IPEDS institutions. The Taulbee institutions are research institutions, while the IPEDS institutions include both research and non-research institutions.

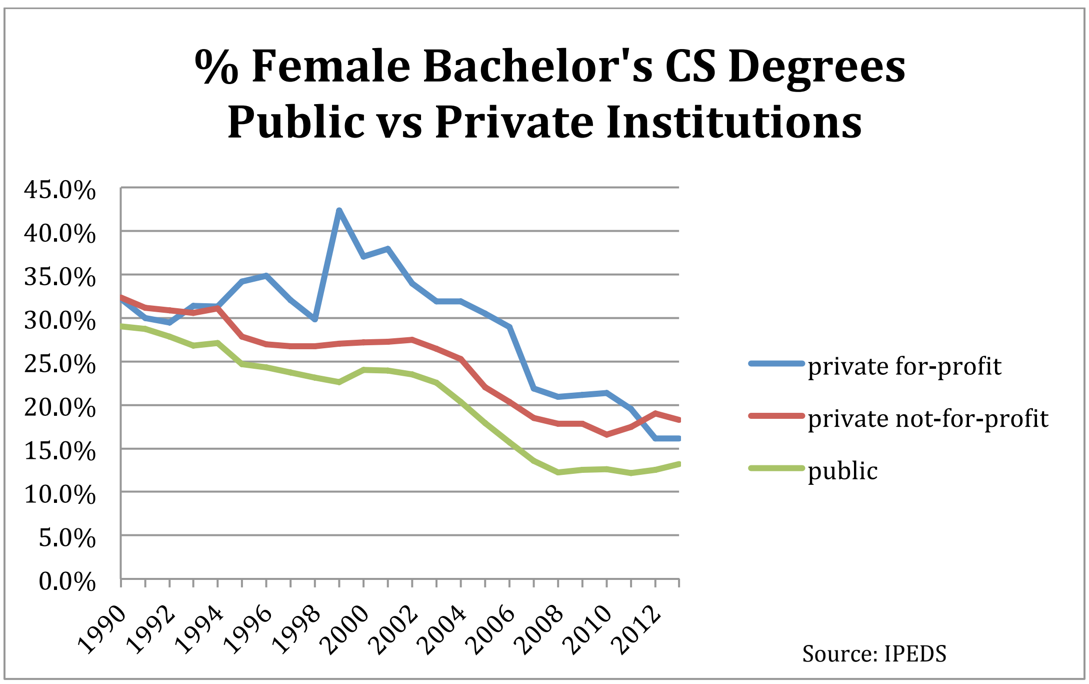


Figure 7. % Female Bachelor's CS Degrees, Public vs. Private Institutions.

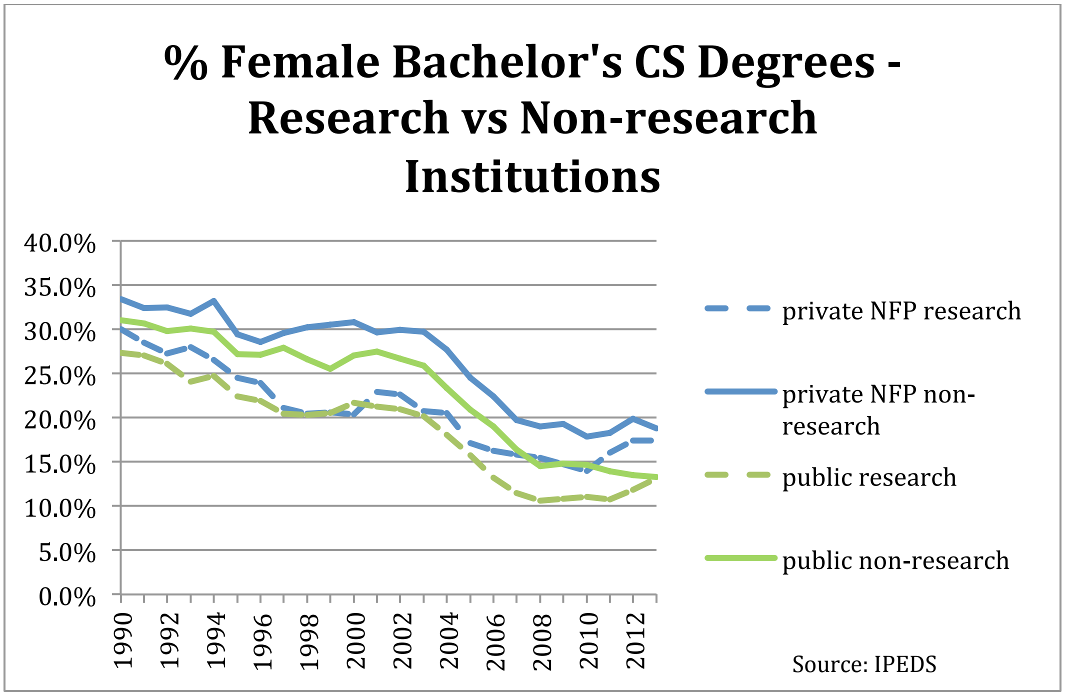


Figure 8. % Female Bachelor's CS Degrees - Research vs. Non-research Institutions.

At the master's level, both private not-for-profit and public show a cycle with a rise from the late 90s through the early 2000s, as was seen in Figure 4 (the overall master's degree graph). The behavior of private for-profit institutions exhibits some of the same overall cyclic characteristics, but is much less smooth. The difference between private not-for-profit and public institutions over the period 1990-2013 is not statistically significant from the matched-pairs rank test, but it is clear from Figure 9 that, in recent years, the percentage of women receiving degrees at private not-for-profit institutions has been lower than that at public institutions.

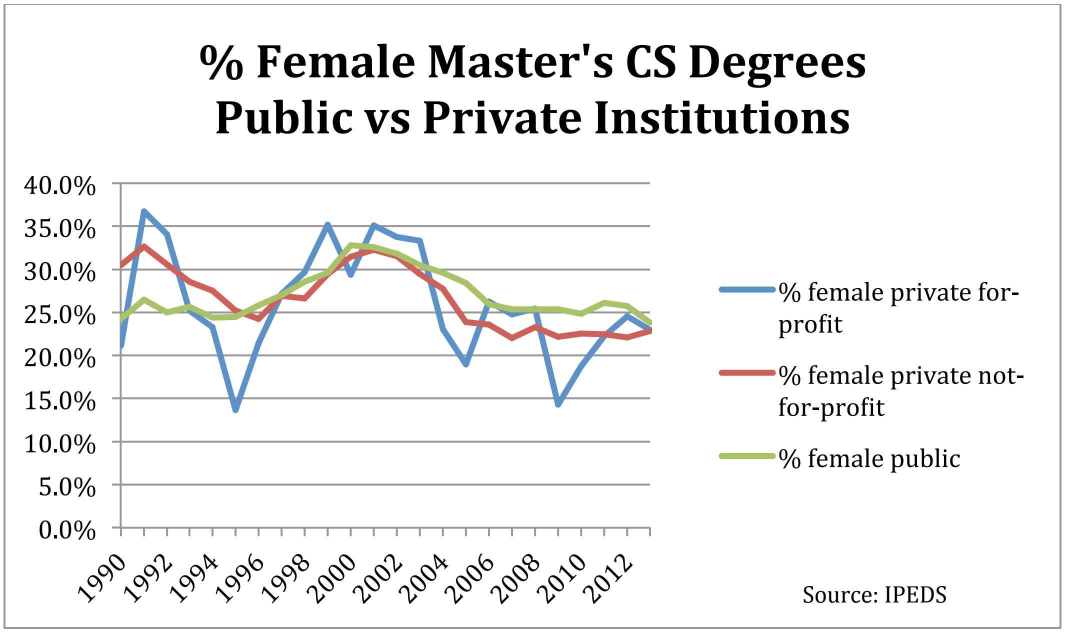


Figure 9. % Female Master's CS Degrees, Public vs. Private Institutions.

At the doctoral level, private not-for-profit institutions have a greater percentage of female graduates than do public institutions (alpha = .01). In Figure 10, both types of institutions show the increasing trend characteristic of the overall doctoral degree trend for women in computer science.

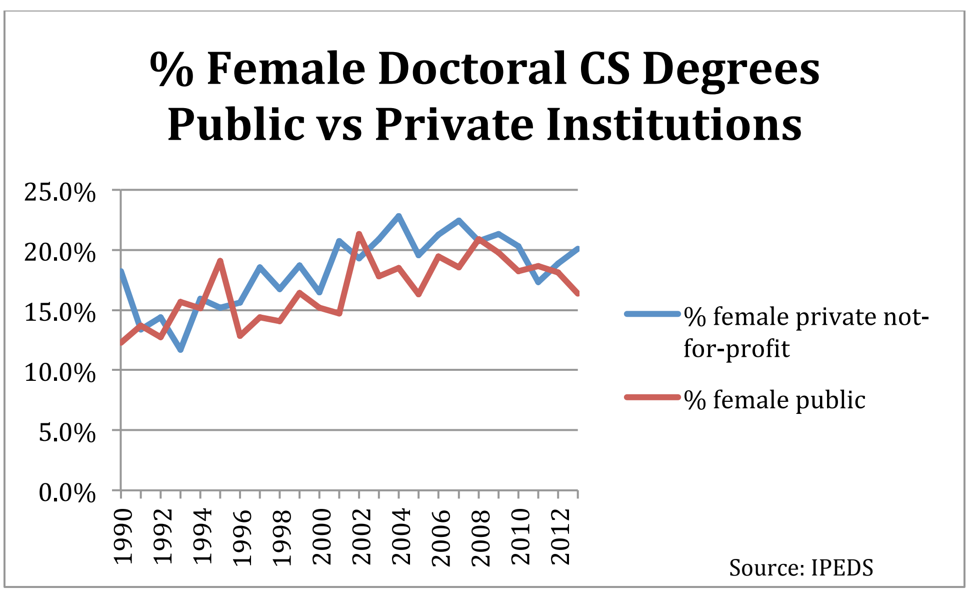


Figure 10. % Female Doctoral CS Degrees, Public vs. Private Institutions.

## Computer Engineering

Computer engineering bachelor's degrees show a significantly higher percentage of degrees to women among private not-for-profit than among public institutions (alpha = .02), as shown in Figure 11. However, most of the evidence for this relationship exists after 2002. Among private not-for-profit institutions, there is no significant difference between the research and non-research institutions in percentage of degrees to women. However, among public institutions, the percentage of degrees to women at non-research institutions is significantly greater than at research institutions (alpha = .01). See Figure 12.

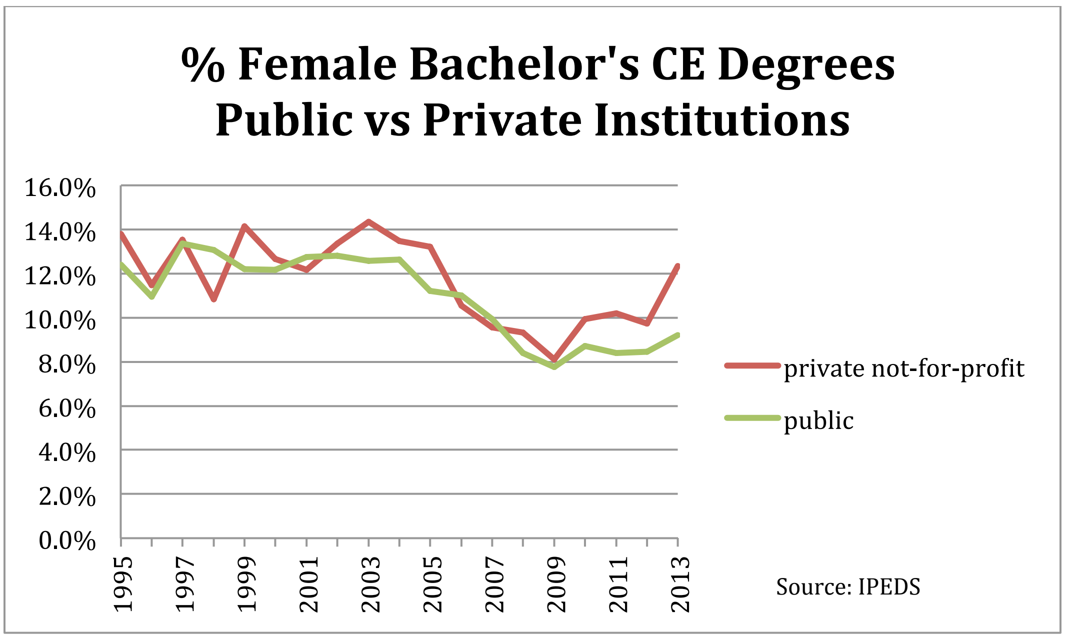


Figure 11. % Female Bachelor's CE Degrees, Public vs. Private Institutions.

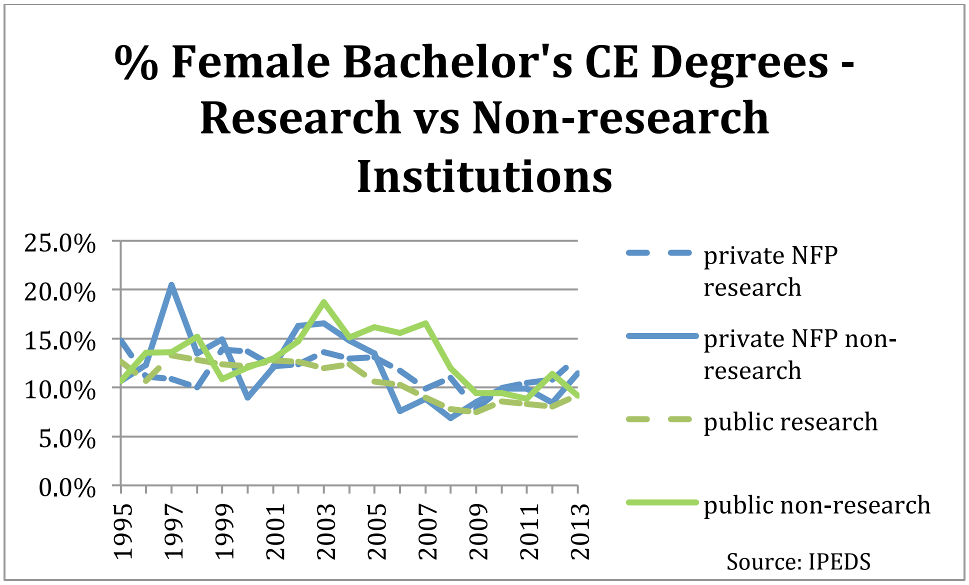


Figure 12. % Female Bachelor's CE Degrees, Research vs. Non-research Institutions.

At the master's degree level, there is no statistically significant difference in the overall trends in the percentage of degrees at private not-for-profit institutions compared with public institutions. However, private not-for-profit institutions awarded a higher percentage of degrees to women than did public institutions for the period 1995-2003, while it has largely been the reverse since then. The public institutions trend from 1995-2013 is not statistically significant, but the private not-for-profit trend is significantly negative (alpha = .01). See Figure 13.

The doctoral degree data was insufficient to compare private not-for-profit and public institution percentages of degrees to women.

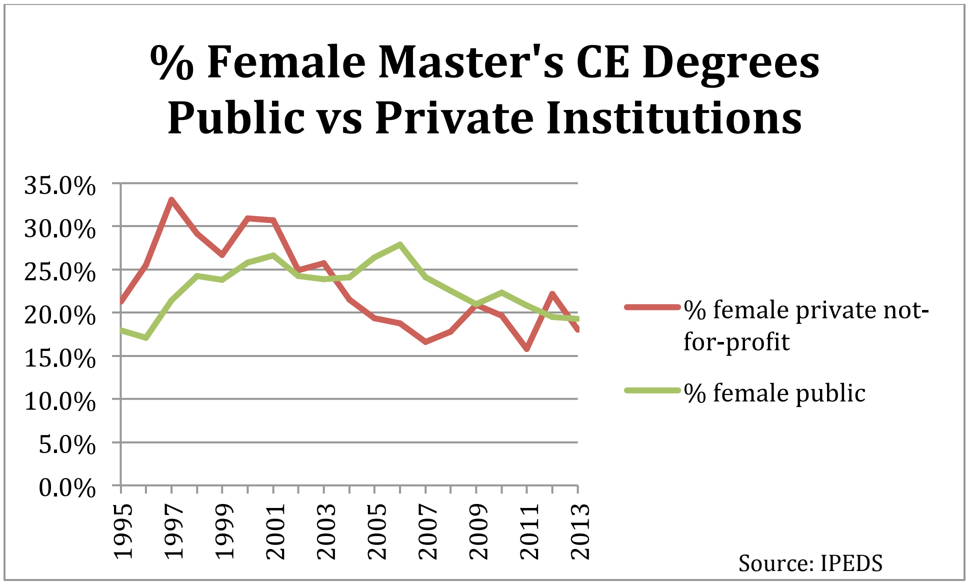


Figure 13. % Female Master's CE Degrees, Public vs. Private Institutions.

The doctoral degree data was insufficient to compare private not-for-profit and public institution percentages of degrees to women.

## Software Engineering

The number of software engineering bachelor's and doctoral degrees is insufficient to be able to do comparative analyses between public and private institutions. At the master's level, there is a significantly greater percentage of degrees awarded to women at public institutions than at private not-for-profit institutions (alpha = .01). This relationship is present in each year from 2003-2013, the only years that data is available for software engineering programs. See Figure 14. It is worth noting that, during this period, computer science programs also showed this relationship between public and private not-for-profit institutions at the master's level, and computer engineering programs showed this relationship in nearly every year during this period.

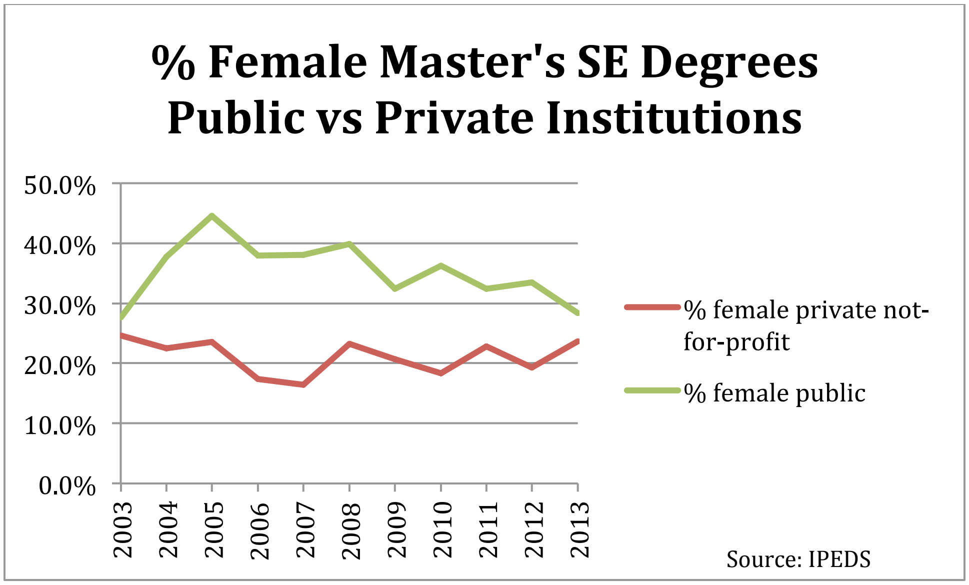


Figure 14. % Female Master's SE Degrees, Public vs. Private Institutions.

## Information Systems

As shown in Figure 15, private not-for-profit institutions have a greater percentage of female information systems bachelor's graduates than do public institutions (alpha = .01). Private for-profit institutions also tend to have a greater percentage of female IS graduates than do public institutions; for-profits have a larger percentage than publics in every year since 2001. There is no statistical significance between the private for-profit and the private not-for-profit trends.

Among private not-for-profit institutions, there is no significant difference in female percentages between research and non-research institutions. See Figure 16. At public institutions, the percentage of female graduates at non-research institutions tends to be greater than that at research institutions, significant at alpha = .05. However, the last five years have seen very little difference between public research and public non-research.

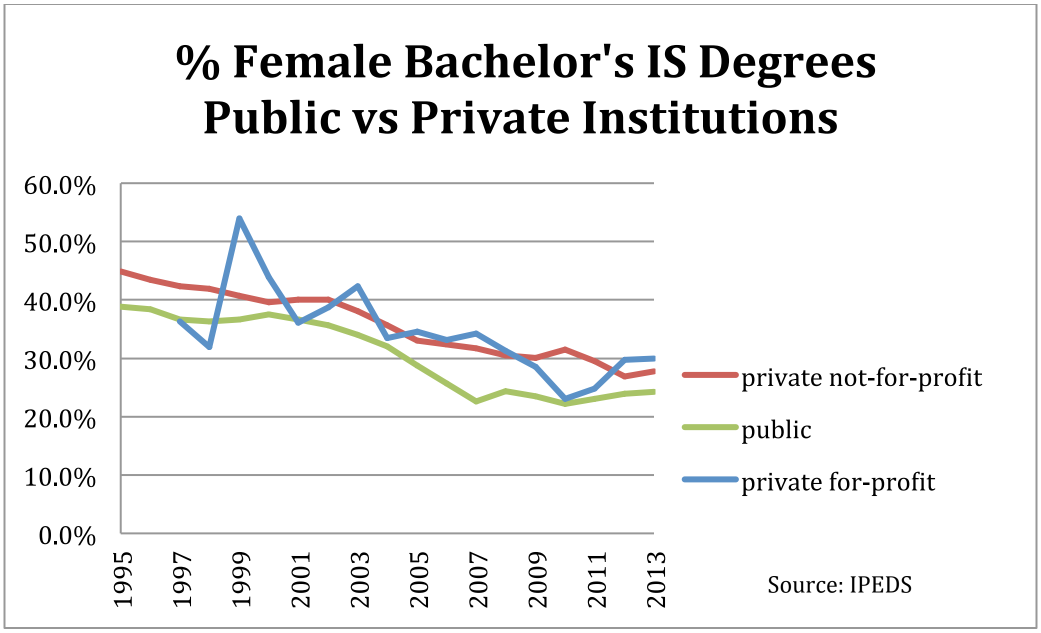


Figure 15. % Female Bachelor's IS Degrees, Public vs. Private Institutions.

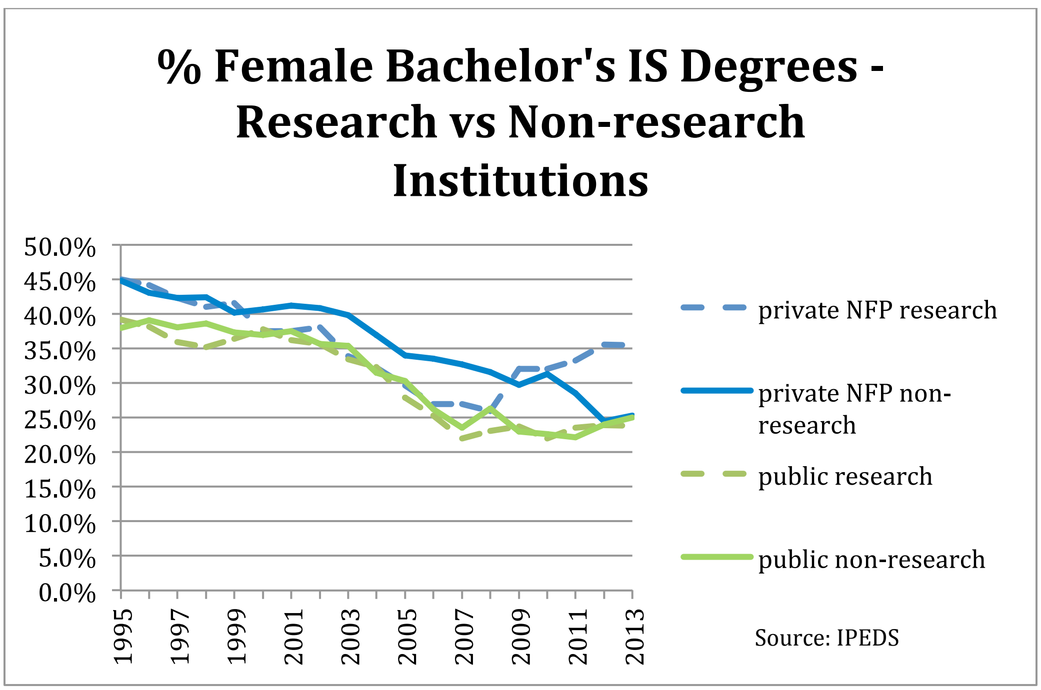


Figure 16. % Female Bachelor's IS Degrees, Research vs. Non-research Institutions.

At the master's level, there is no significant difference between public and private not-for-profit institutions, as shown in Figure 17. Here there is not the clear trend since 2003 that there was for the disciplines previously discussed. At the doctoral level, there is insufficient data with which to analyze public vs private institutions.

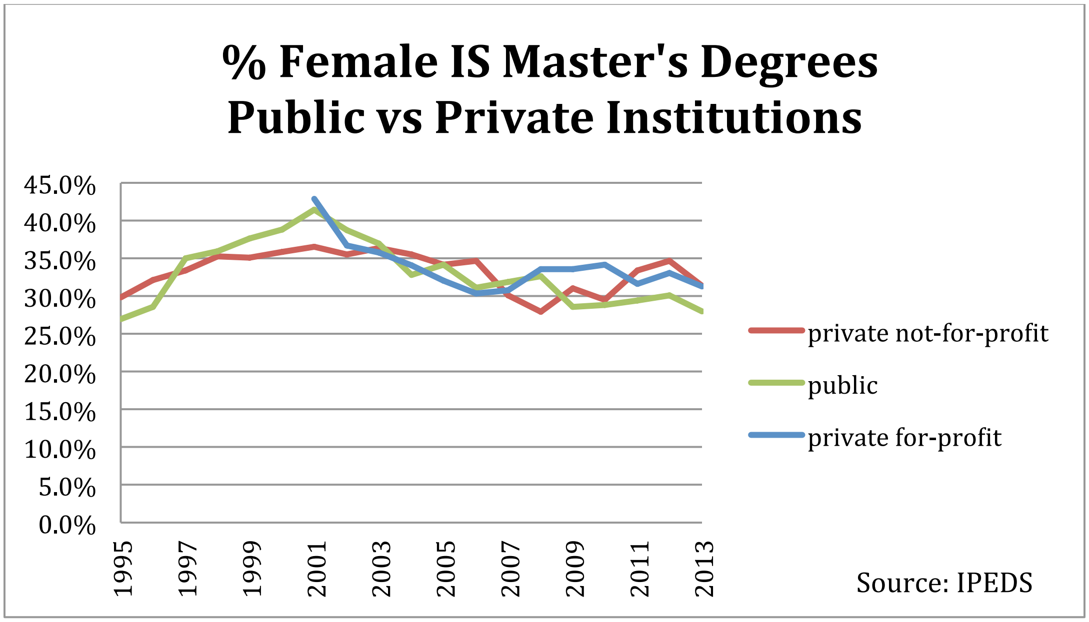


Figure 17. % Female IS Master's Degrees, Public vs. Private Institutions.

## Information Technology

There is a greater percentage of women graduating with IT bachelor's degrees from private not-for-profit institutions than there is from public institutions, at alpha = .01. There also is a greater percentage of women graduating from private not-for-profit institutions than there is from private for-profit institutions, at alpha = .05. See Figure 18.

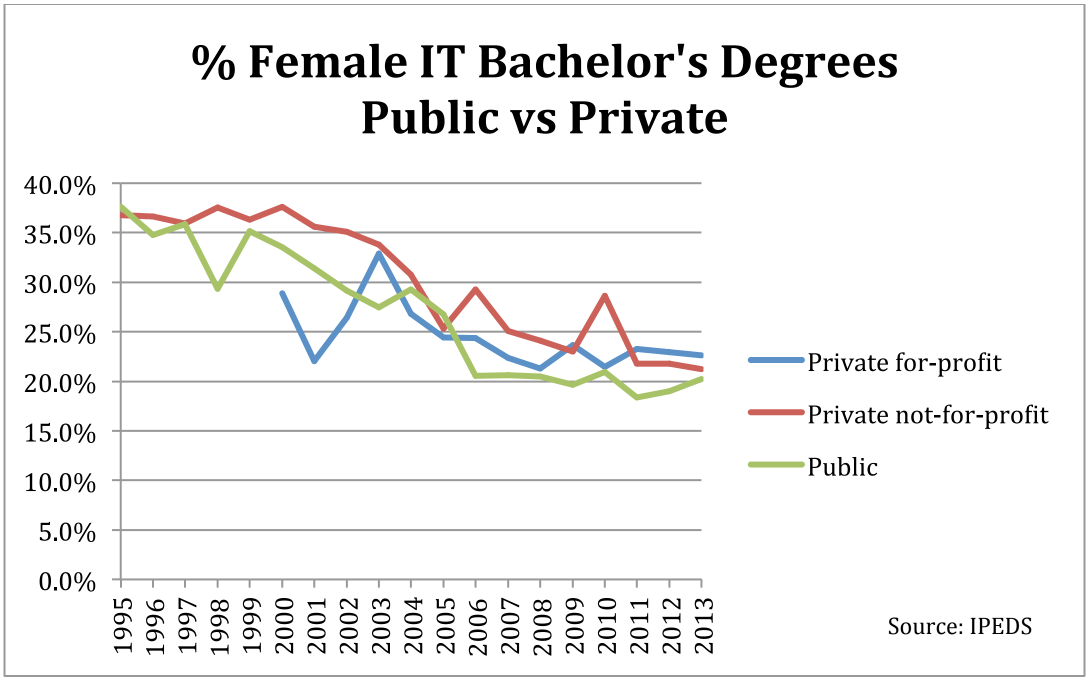


Figure 18. % Female IT Bachelor's Degrees, Public vs. Private.

At the master's level, the percentage of women graduates at private not-for-profit institutions is greater than that at public institutions except in the years 2004 and 2005, as shown in Figure 19. The difference between private not-for-profit and public is significant at alpha = .01. Doctoral data is insufficient for analysis.

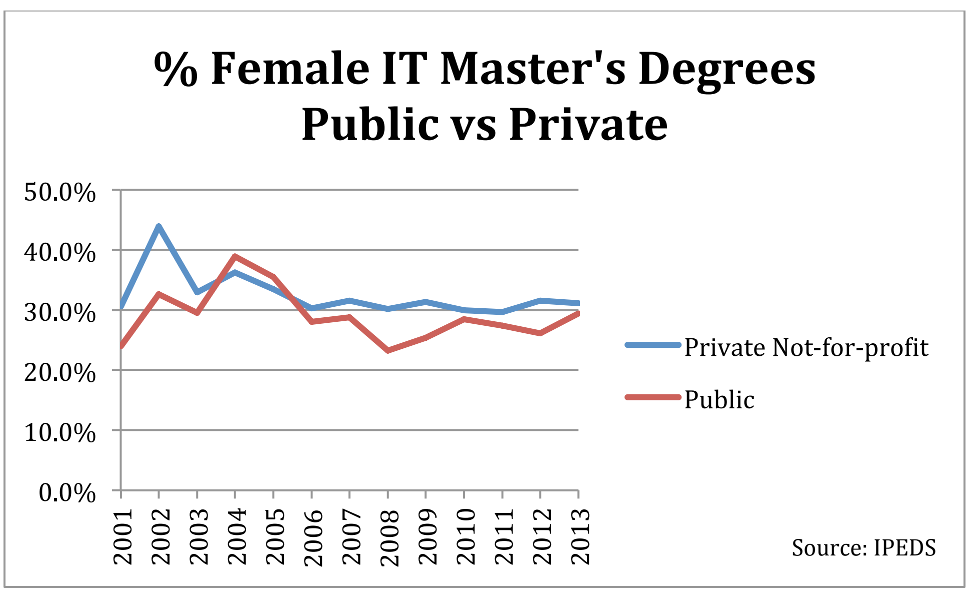


Figure 19. % Female IT Master's Degrees, Public vs. Private.

## Information Science

Private not-for-profit institutions have produced a greater percentage of female information science bachelor's degrees than have public institutions in almost every year, as shown in Figure 20. The difference between the two types of institutions is significant at alpha = .01. In the 1990s and early 2000s, private not-for-profit institutions produced a greater percentage of female bachelor's graduates than did private for-profit institutions. However, in recent years, the reverse is true. The aggregate trends are not statistically significant.

Among private not-for-profit institutions, non-research institutions produce more female bachelor's graduates than do research institutions, significant at alpha = .01. At public institutions, there is not a significant difference between percentages at research and non-research institutions. See Figure 21.

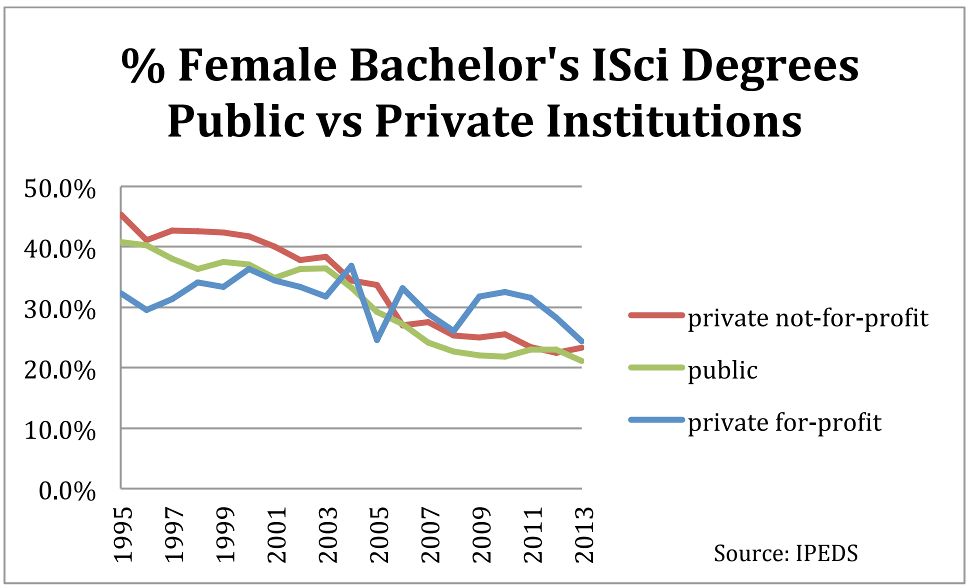


Figure 20. % Female Bachelor's ISci Degrees, Public vs. Private Institutions.

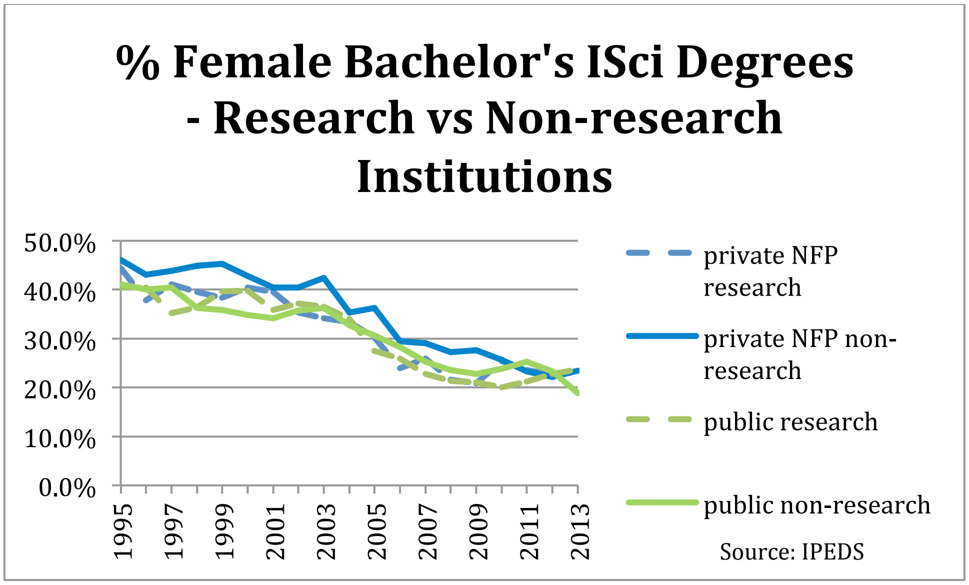


Figure 21. % Female Bachelor's ISci Degrees, Research vs. Non-research Institutions.

At the master's level (Figure 22), public institutions produce a greater percentage than private not-for-profit institutions, significant at alpha = .01. The graph also shows that private for-profit institutions have produced a greater percentage of female graduates than have private not-for-profit institutions in nearly every year since 1998. There are too few graduates to analyze doctoral level data.

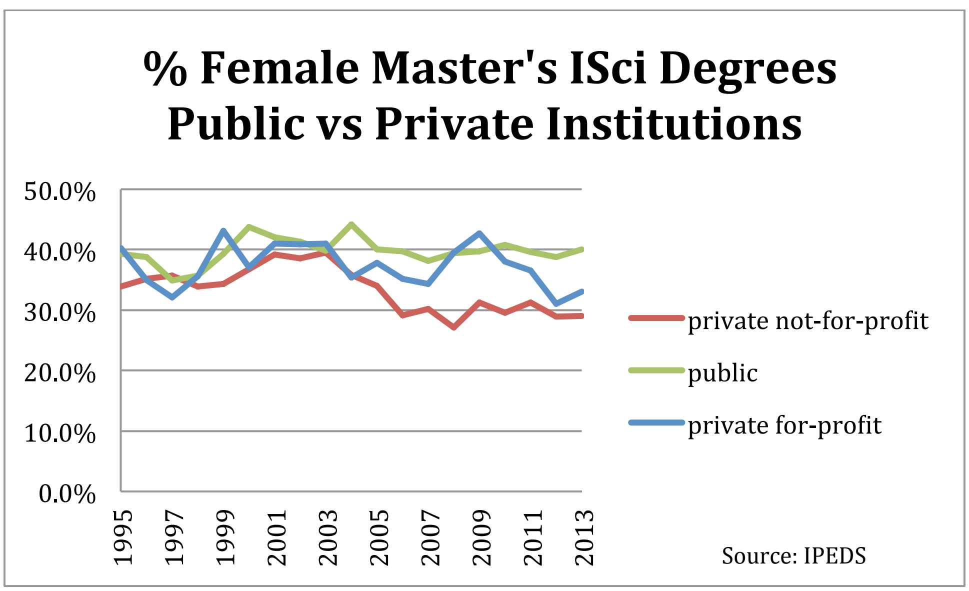


Figure 22. % Female Master's ISci Degrees, Public vs. Private Institutions.

## Security

There is too little security data to analyze public institutions against private institutions at any degree level. The most useful information is present at the bachelor's level, where there appears to be some increase for private for-profit and public institutions, but no discernible pattern for private not-for-profit institutions, as shown in Figure 23. The vast majority of bachelor's recipients are at for-profit institutions and at non-research institutions. At the master's level, the vast majority of degrees are at private institutions, both for-profit and not-for-profit, as shown in Figure 24. Here again, there appears to be an increasing trend for for-profit and no discernible trend for not-for-profit institutions.

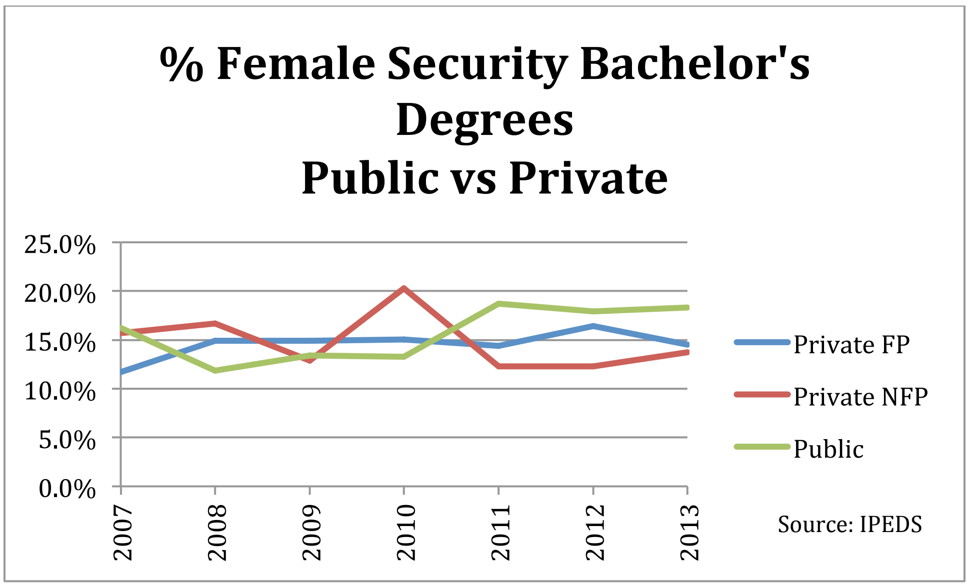


Figure 23. % Female Security Bachelor's Degrees, Public vs. Private.

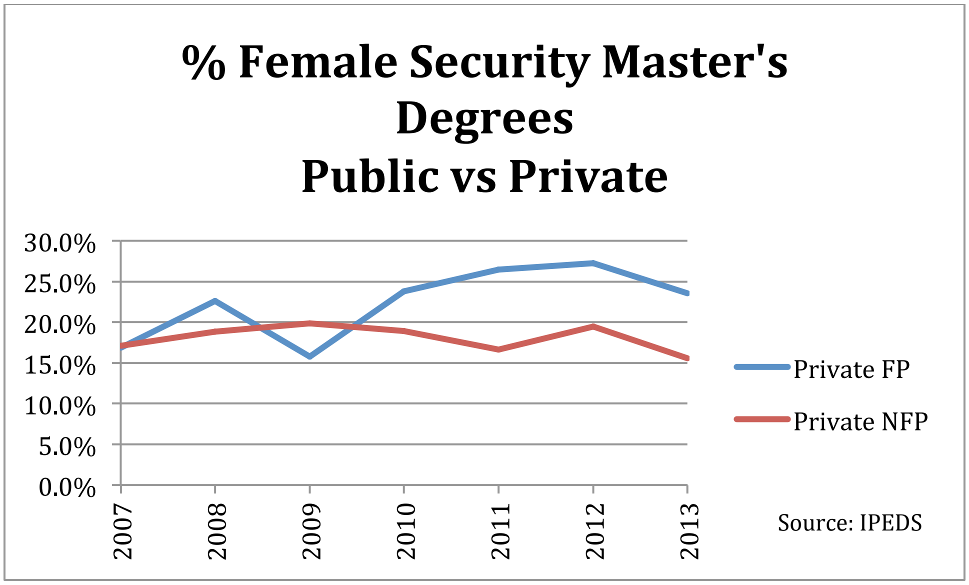


Figure 24. % Female Security Master's Degrees, Public vs. Private.

## Interdisciplinary

In our earlier discussion of overall bachelor's trends, we observed that the interdisciplinary area showed no significant trend, with increasing values in recent years. When we examine the differences between public and private institutions, we see that, in fact, the private institutions have negative trends (for-profit significant at alpha = .05, not-for-profit significant at alpha = .01), while public institutions have a positive trend, significant at alpha = .01. See Figure 25.

Overall, private not-for-profit institutions have a significantly greater (at alpha = .02) percentage of female graduates than do public institutions, but the graph clearly shows that this is due to the pre-2003 period. Private not-for-profit institutions percentages clearly exceed those for private for-profit (alpha = .01).

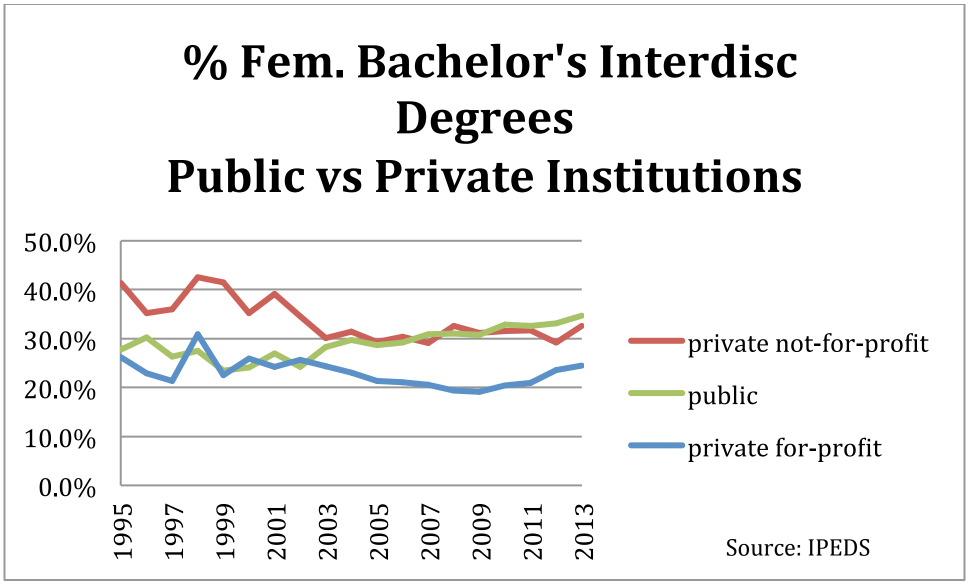


Figure 25. % Female Bachelor's Interdisciplinary Degrees, Public vs. Private Institutions.

Among private not-for-profit institutions, there is no significant difference between percentages of female graduates at research vs non-research institutions. However, at public institutions, there is a greater percentage (significant at alpha = .05) at research institutions. See Figure 26.

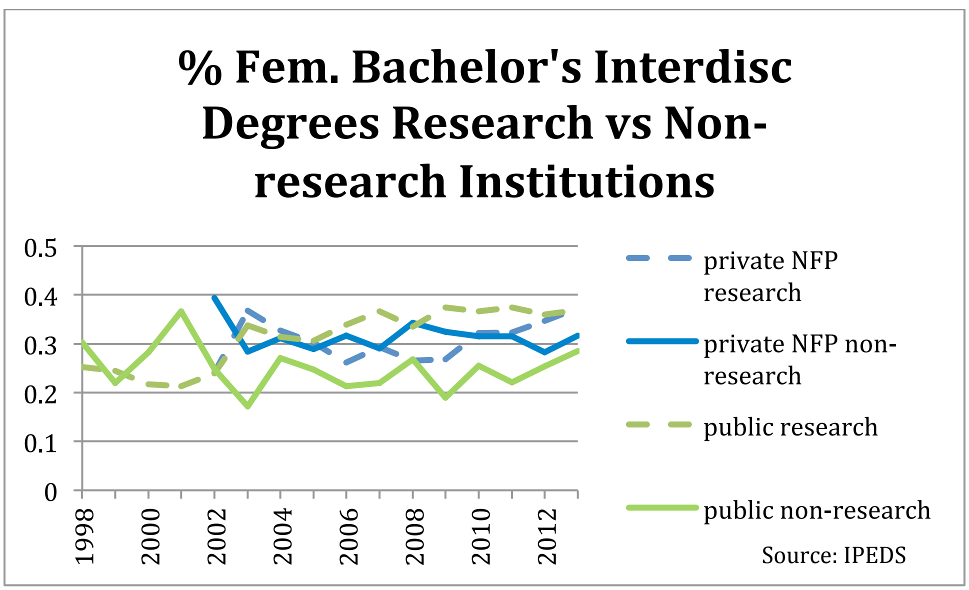


Figure 26. % Female Bachelor's Interdisciplinary Degrees, Research vs. Non-research Institutions.

At the master's level, there is a greater percentage of women at public institutions compared with private not-for-profit institutions (significant at alpha = .10), as shown in Figure 27. There are too few graduates at the doctoral level to do an analysis of public vs private institutions.

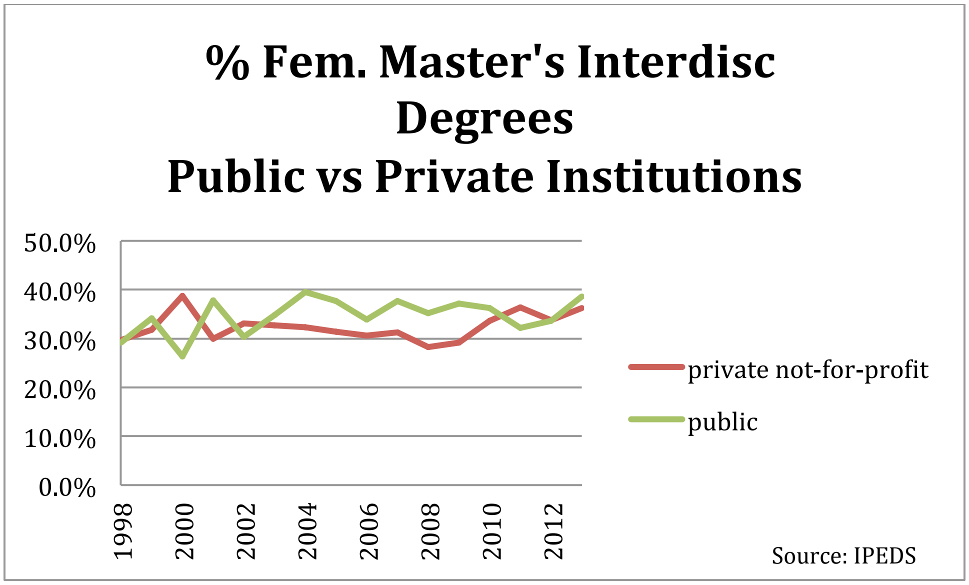


Figure 27. % Female Master's Interdisciplinary Degrees, Public vs. Private Institutions.

## Synthesis of Results Based on Institutional Characteristics

Table 6 summarizes the results of the analyses based on institutional characteristics. Our hypothesis that for-profit institutions will grant a higher percentage of bachelor's degrees to women than will not-for-profits was borne out only in computer science. The hypothesis that non-research institutions will grant a higher percentage of bachelor's degrees to women than will research institutions also gives mixed results. It is confirmed for computer science for both public and private not-for-profit institutions. Among private not-for-profit institutions, only the information science also shows this result; the other four areas where comparisons were possible showed no significant difference. And among public institutions, CE, IS and IT showed varying degrees of significance in the hypothesized direction, while information science showed no significant difference and the interdisciplinary area showed a difference in favor of research institutions.

Though we had no hypothesis about the relationship between public and private not-for-profit institutions, at the bachelor's level all disciplines in which a comparison was possible favored private not-for-profit institutions. Master's results were mixed across the different disciplines.

Table 6. IPEDS Data Analysis Based on Institutional Characteristics.

| | CS | CE | SE | IS | IT | ISci | Sec | Idsc |
|---|---|---|---|---|---|---|---|---|
| BACHELOR's | | | | | | | | |
| Private NFP: Private FP | <*** | na | na | ↔ | >* | ↔ | na | >*** |
| Private NFP: Public | >*** | >** | na | >*** | >*** | >*** | na | >** |
| Private NFP Non-rsh: Research | >*** | ↔ | na | ↔ | ↔ | >*** | na | ↔ |
| Public Non-rsh: Research | >*** | >*** | na | >* | >† | ↔ | na | <* |
| | | | | | | | | |
| MASTER'S | | | | | | | | |
| Private NFP: Public | ↔ | ↔ | <*** | ↔ | >*** | <*** | na | <† |
| | | | | | | | | |
| DOCTORAL | | | | | | | | |
| Private NFP: Public | >*** | na | na | na | na | na | na | na |

| Table Key for A:B comparisons | | | |
|---|---|---|---|
| > | A > B | † | significance level = .10 |
| < | A < B | × | significance level = .05 |
| ↔ | no significant difference | ×× | significance level = .02 |
| | | ××× | significance level = .01 |

Start year for analyses: CS 1990; CE 1995; SE 2003; IS 1995 except FP vs NFP (1997); Isci 1995; IT FP vs NFP (2000), BS NFP vs Public (1995), BS NFP research vs non-research (2003), BS Public research vs non-research (1999), MS NFP vs Pubic (2001); Idsc FP vs NFP and BS NFP vs Public (1995), BS NFP research vs non-research (2002), BS Public research vs non-research and MS NFP vs Pubic (1998)

## Additional Analysis of Non-Research Institutions

The majority of institutions within our Non-research classification are those within Carnegie categories "Baccalaureate Colleges" (BACC) and "Masters Colleges and

Universities" (MAST). Baccalaureate Colleges award fewer than 50 master's degrees institution-wide. We were interested in seeing if the representation of women differed in non-research institutions whose classification suggested that it had little graduate program activity from those whose classification suggested more prominence of its graduate programs.

We examined the differences between these two categories of institutions for the four computing disciplines producing the greatest number of degrees (CS, IS, IT and Idsc). Figs. 28 and 29 show the trends within CS at private not-for-profit and public institutions, respectively. Clearly, the individual trends for BACC and MAST institutions are very similar to each other and to those for all non-research institutions combined. Table 7 summarizes the comparisons for each of the four disciplines. It indicates that there is little difference in the BACC and MAST trends within any of the disciplines with the exception of Idsc public institutions, where the overall non-research trend is significant at alpha = .05 but the BACC and MAST trends are not significant. This is due to differences in the period during which there is sufficient data to analyze the different cells' trends. If the overall Idsc trend is analyzed during the period 2002-2013 instead of 1995-2013, the trend is not significant, which is consistent with the BACC and MAST findings.

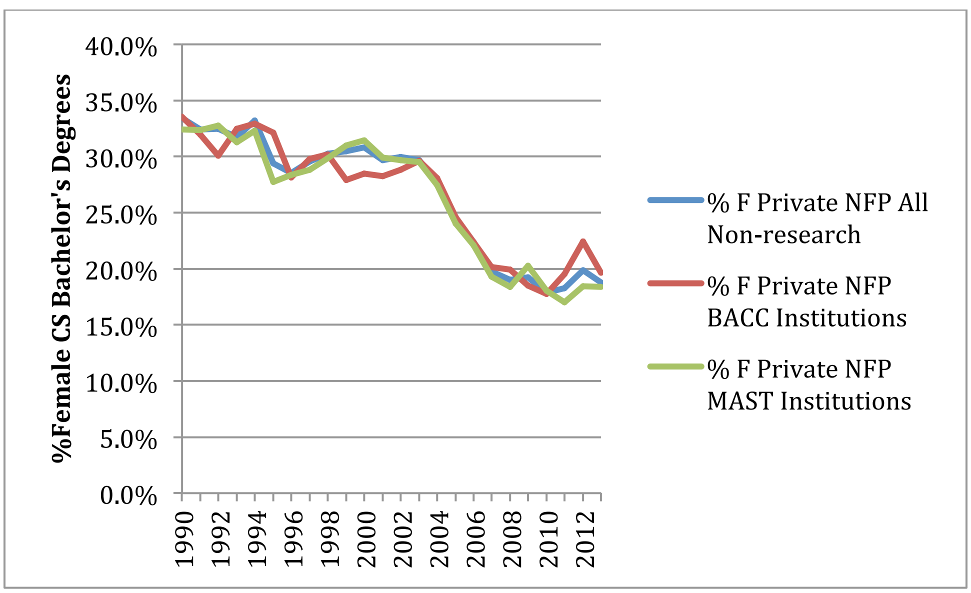


Figure 28. % Female CS Bachelor's at Private NFP BACC vs. MAST Institutions.

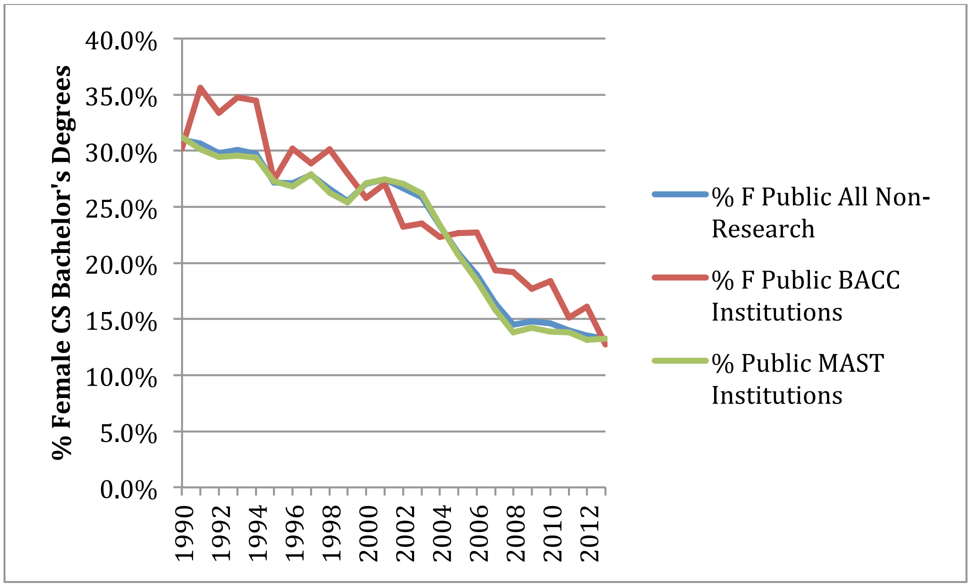


Figure 29. % Female CS Bachelor's at Public NFP BACC vs MAST Institutions.

Table 7. Bachelor's Degree Trends for Women at BACC and MAST Institutions.

| Analysis | CS | IS | IT | Idsc |
|---|---|---|---|---|
| Private Not-for-profit | | | | |
| All non-research institutions | ↓*** | ↓*** | ↓*** | ↓*** |
| BACC institutions | ↓*** | ↓*** | ↓*** | ↓*** |
| MAST institutions | ↓*** | ↓*** | ↓*** | ↓** |
| | | | | |
| Public | | | | |
| All non-research institutions | ↓*** | ↓*** | ↓*** | ↓* |
| BACC institutions | ↓*** | ↓*** | ↓Ɨ | ↔ |
| MAST institutions | ↓*** | ↓*** | ↓*** | ↔ |
| Note: IT NFP begins 1997; IT Public BACC begins 2004; Idsc PRIV NFP begins 1999; | | | | |
| Idsc PUBLIC BACC begins 2004; Idsc PUBLIC MAST begins 2002 | | | | |
| All other IS, IT, Idsc begin 1995; CS begins 1990 | | | | |
| Key is the same as for Table 3. | | | | |

### *Individual Characteristics*

To analyze differences based on individual characteristics, for each disciplinary area we disaggregated the IPEDS degree production data according to whether the individual obtaining the degree was a majority, minority, or non-resident.

Table 8 shows the total number of bachelor's degrees granted to men and women combined in 2013, for each discipline by individual characteristic.

Table 8. Total Bachelor's Degrees 2013 by Individual Characteristic. Source: IPEDS.

| | | Nonresident | | Majority | | Minority | | Total |
|---|---|---|---|---|---|---|---|---|
| CS | | 1,700 | | 17,108 | | 3,748 | | 22,556 |
| CE | | 381 | | 3,341 | | 757 | | 4,479 |
| SE | | 32 | | 437 | | 93 | | 562 |
| IS | | 494 | | 6,253 | | 2,506 | | 9,253 |
| IT | | 364 | | 8,707 | | 2,956 | | 12,027 |
| Isci | | 314 | | 3,881 | | 1,432 | | 5,627 |
| Sec | | 34 | | 2,438 | | 1,183 | | 3,655 |
| Idsc | | 315 | | 5,936 | | 2,111 | | 8,362 |
| | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Total | | 3,634 | | 48,101 | | 14,786 | | 66,521 |

Our hypotheses are that a) minority degree recipients are more likely to be women than are majority degree recipients; and b) non-resident degree recipients are about as likely to be women as are majority women. We report the results by discipline. We also compared selected ethnicity trends with respect to institutional characteristics.

## Computer Science

The negative trend in the percentage of CS bachelor's degrees awarded to women between 1990 and 2013 is present within all three ethnicity categories, as shown in Figure 30, with significance level .01 in each case. Minority bachelor's degree recipients are more likely to be women than are non-resident recipients, who in turn are more likely to be women than are majority recipients.

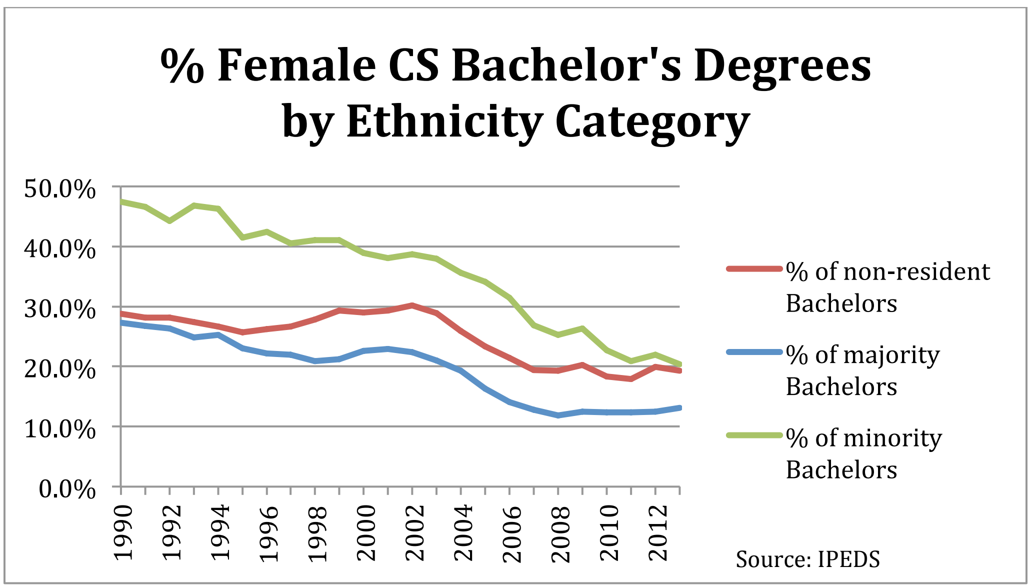


Figure 30. % Female CS Bachelor's Degrees by Ethnicity Category.

Women receive a higher percentage of bachelor's degrees awarded to majorities at private not-for-profit institutions than they do at public institutions. The same is true for degrees awarded to minorities (alpha = .01), though between 1990 and 2001 there was little difference between private not-for-profit and public institutions in the percentage of minority degree recipients who were women. See Figures 31 and 32.

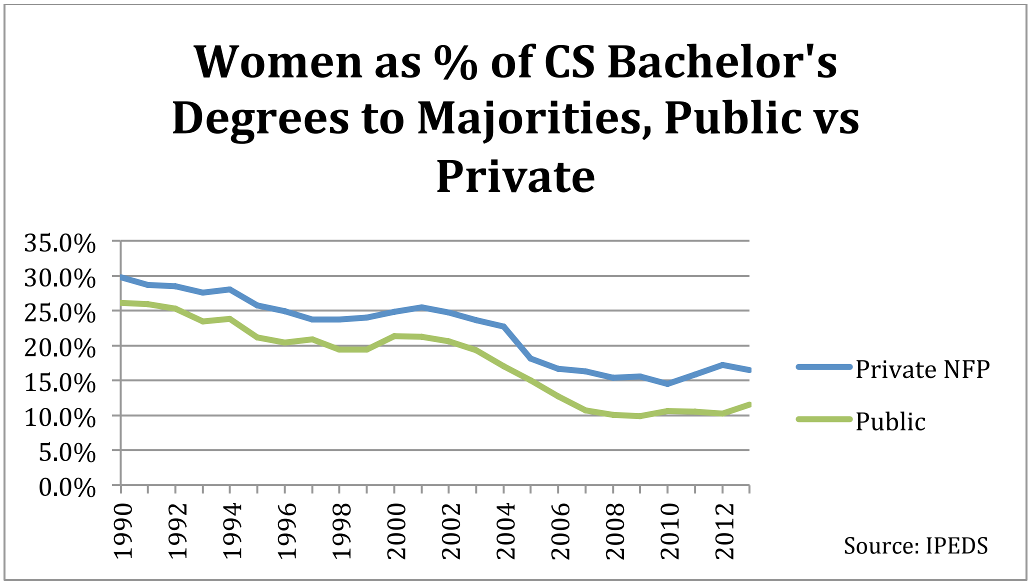


Figure 31. Women as % of CS Bachelor's Degrees to Majorities, Public vs. Private.

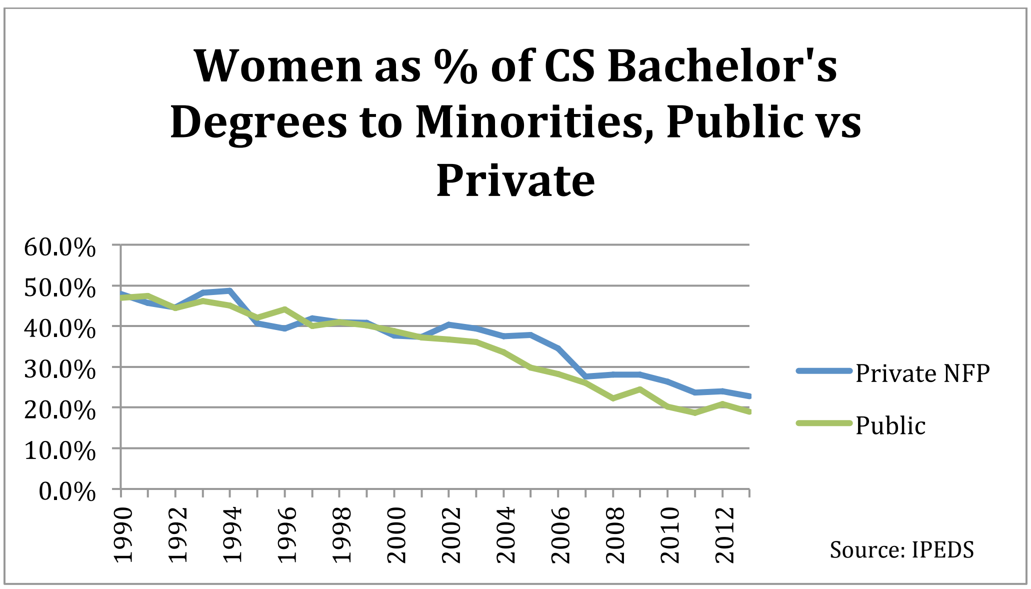


Figure 32. Women as % of CS Bachelor's Degrees to Minorities, Public vs. Private.

As Figures 33 and 34 show (albeit for only a subset of years), women historically have received a higher percentage of bachelor's degrees awarded to majorities at non-research institutions than they do at research institutions, and the same is true for bachelor's degrees awarded to minorities. This is consistent with the overall comparison between CS degrees from research and non-research institutions described in the section on institutional characteristics. However, the situation for majorities changed in 2013, and the difference between research and non-research institutions has narrowed for minorities in the past two years.

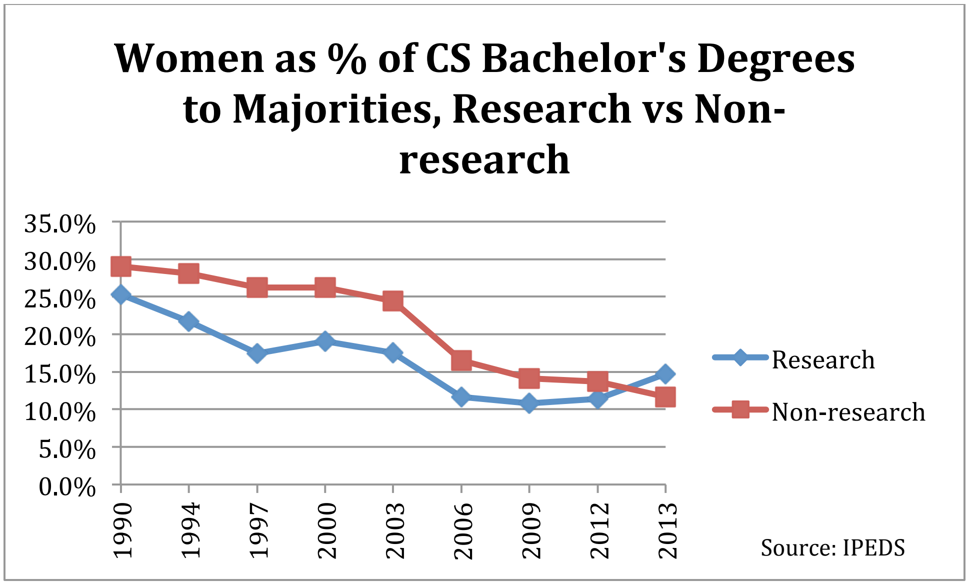


Figure 33. Women as % of CS Bachelor's Degrees to Majorities, Research vs. Non-research.

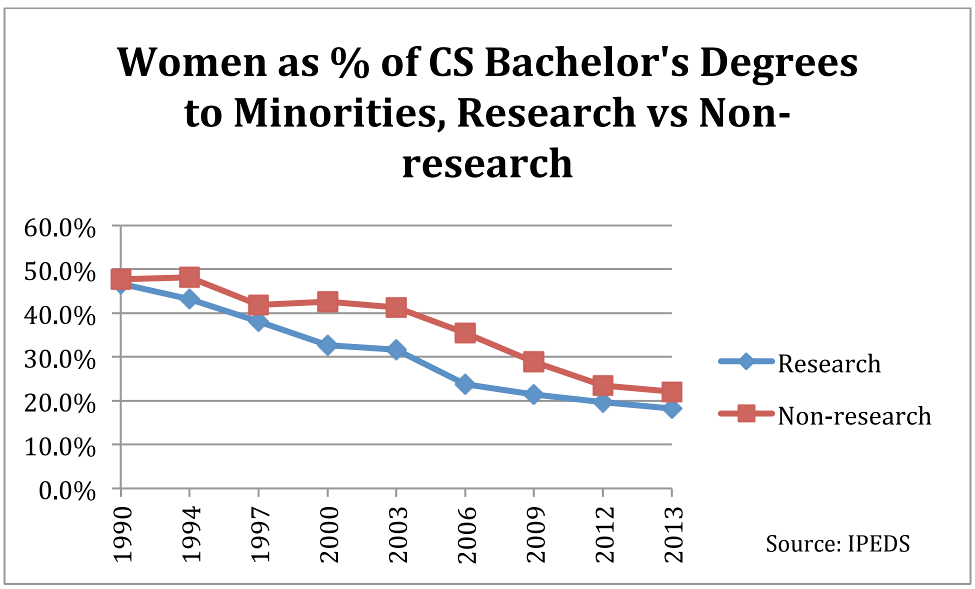


Figure 34. Women as % of CS Bachelor's Degrees to Minorities, Research vs. Non-research.

At the master's level, there is an overall negative trend (significant at alpha = .01) in the percentage of degrees awarded to women among majority degree recipients and among minority degree recipients. However, there is a positive trend (significant at alpha = .05) in the percentage of non-resident degree recipients who are women. The majority and minority trends are most evident after the turn of the millennium. The non-resident trend shows a sharp rise during the dot-com boom of the late 90s, followed by a decline after 2001 and a leveling off beginning around

2006. Figure 35 indicates that minority degree recipients are more likely to be women than are majority degree recipients and that, since 1996, non-resident degree recipients are more likely to be women than are majority degree recipients, with the gap widening in recent years.

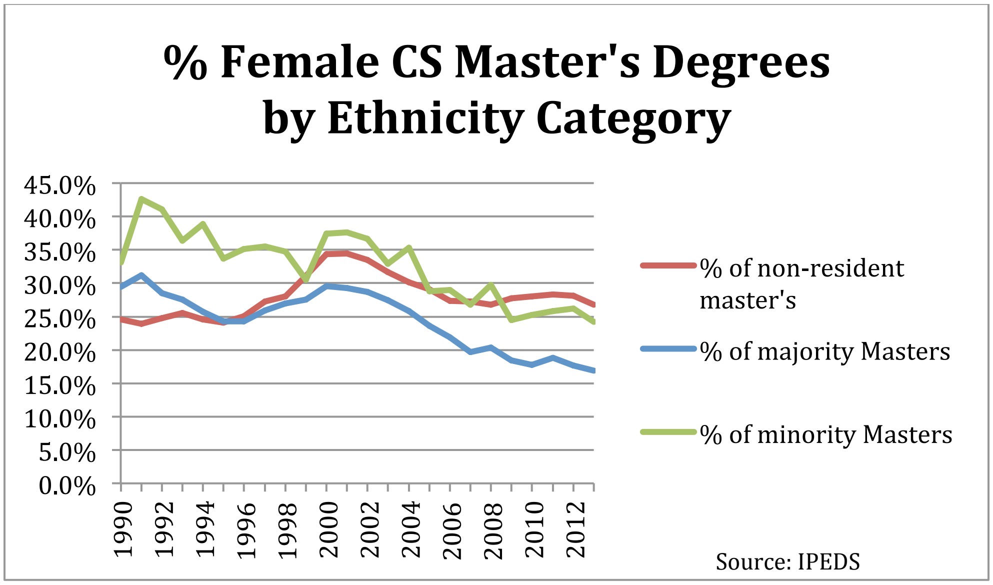


Figure 35. % Female CS Master's Degrees by Ethnicity Category.

There is no significant trend among majority doctoral degree awardees in the percentage who are women. (See Figure 36.) However, there is a positive trend among non-resident doctoral degree awardees in the percentage who are women (significant at alpha = .01). Since 2006, women have obtained a greater percentage of computer science degrees among non-resident doctorates than among majority doctorates, although in 2013 this difference was very small. There are too few minority doctoral degree awardees to analyze the trend.

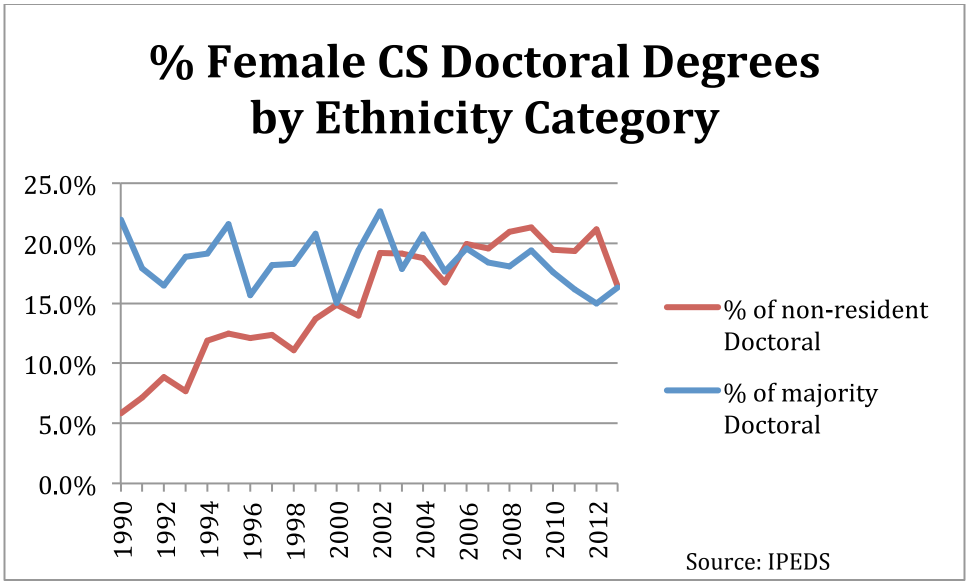


Figure 36. % Female CS Doctoral Degrees by Ethnicity Category.

## Computer Engineering

In computer engineering, there has been a negative trend in the percentage of majority bachelor's degrees awarded to women, and also a negative trend in the percentage of minority bachelor's degrees awarded to women (both at alpha = .01). No significant trend is present among female non-resident degree awardees. Women have obtained a greater percentage of bachelor's degrees among minority degree recipients than they have among majority degree recipients, and women have obtained a greater percentage of bachelor's degrees among non-resident degree recipients than they have among majority degree recipients. Women's share of computer engineering bachelor's degrees among minorities and non-residents has been comparable since 2007. Since 2009, there is some indication of an increasing fraction of women among majority bachelor's recipients. See Figure 37.

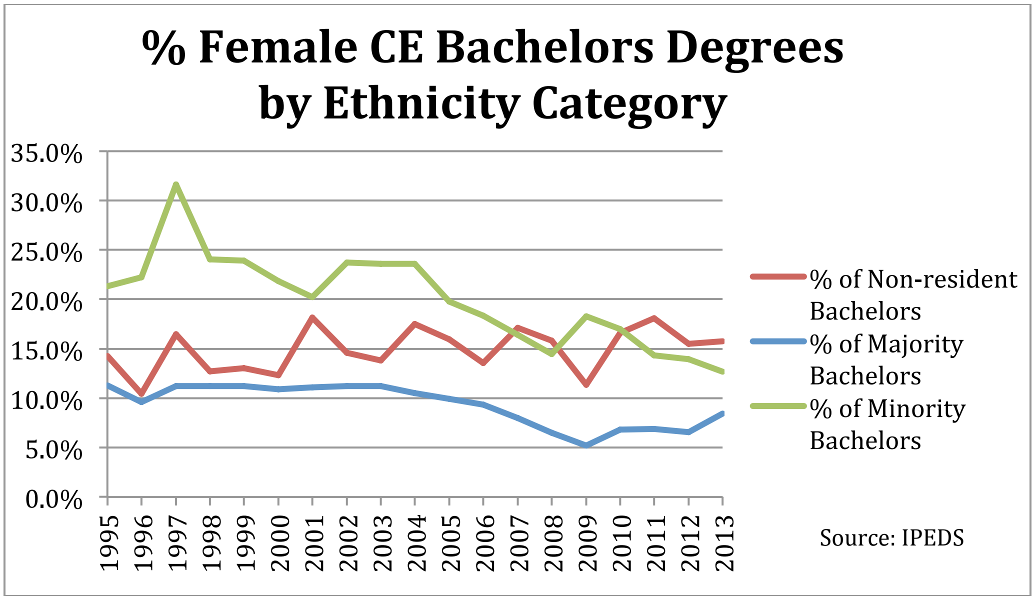


Figure 37. % Female CE Bachelor's Degrees by Ethnicity Category.

There is no significant trend in the percentage of master's degrees awarded to women among non-resident degree awardees. The minority trend shows large fluctuations from year to year due to smaller total numbers of female graduates; the trend is negative (significant at alpha = .10). The trend among majority degree awardees also is negative (significant at alpha = .01). Women have obtained a greater percentage of master's degrees among minorities than they have among majorities in every year except 2003 and 2011 (the overall comparison is significant at alpha = .10), have obtained a greater percentage among non-residents than they have among minorities in almost every year since 2006, and have obtained a greater percentage among non-residents than they have among majorities in every year since 1996. See Figure 38.

There is an insufficient amount of data about doctoral degree awardees to do ethnicity trends or comparisons.

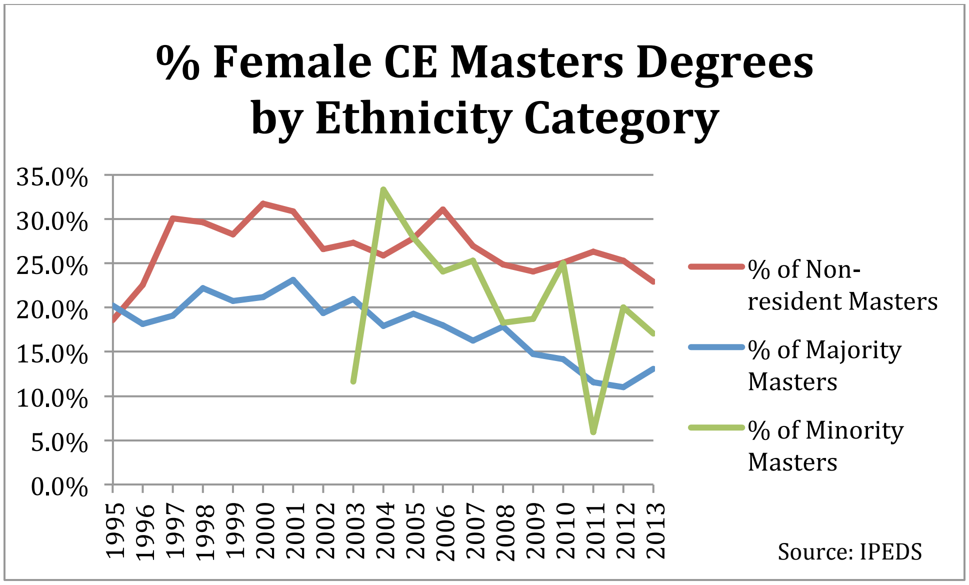


Figure 38. % Female CE Masters Degrees by Ethnicity Category.

## Software Engineering

In the software engineering area, there are few bachelor's graduates who are either non-residents or minorities. The trend for majorities is negative, significant at alpha = .10, shown in Figure 39.

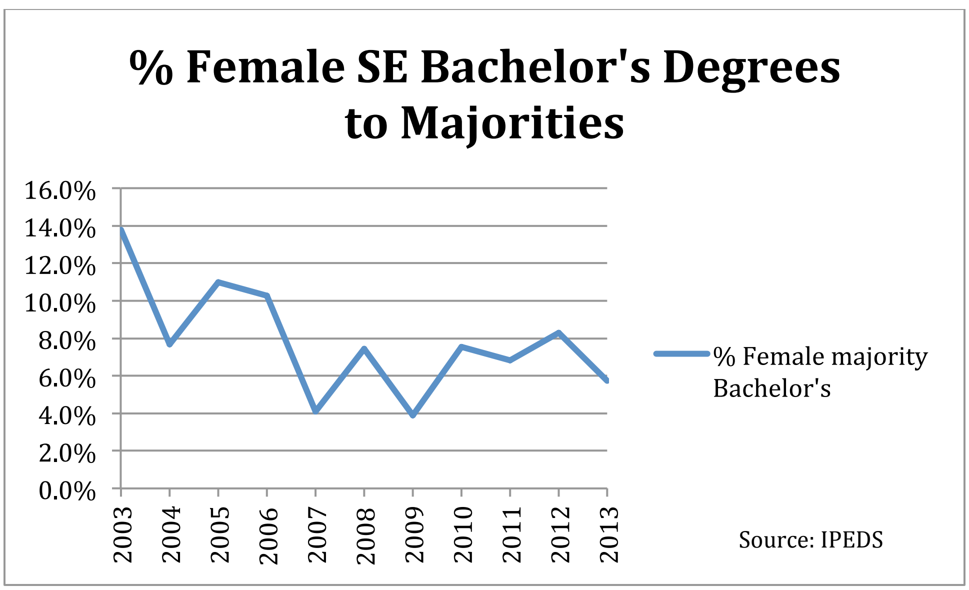


Figure 39. % Female SE Bachelor's Degrees to Majorities.

At the master's level, there again are too few minorities for analysis. Neither the percentage of women among non-resident master's degrees nor the percentage among majority master's degrees shows a significant trend (Figure 40). In most years, the percentage of women among non-resident master's degrees exceeded that among majority master's degrees, though the two graphs are not statistically significant from one another. There are very few doctoral degrees in any ethnicity area.

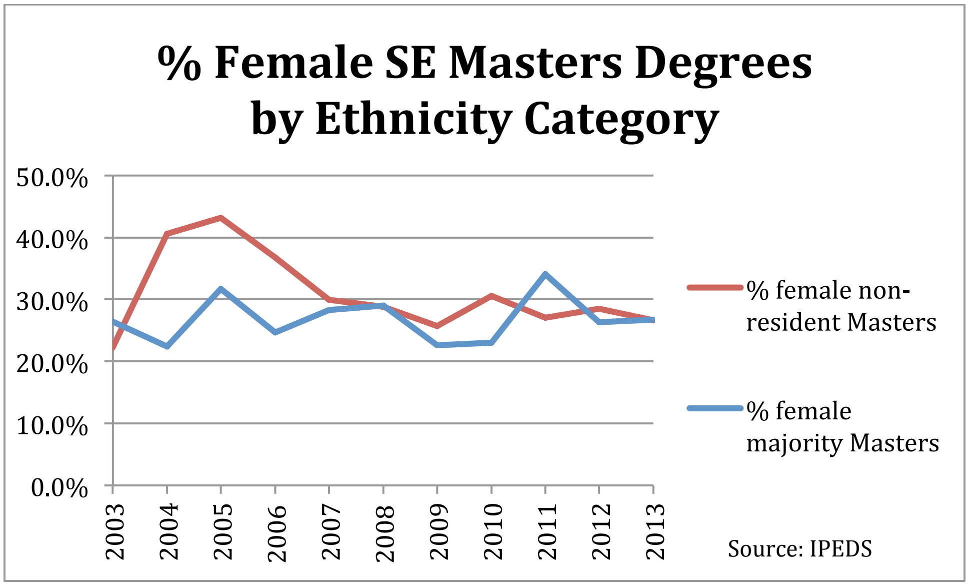


Figure 40. % Female SE Master's Degrees by Ethnicity Category.

## Information Systems

The percentage of majority, minority, and non-resident bachelor's degrees in information systems that were awarded to women each exhibits a negative trend, significant at alpha = .01. Furthermore, minority bachelor's degree recipients are more likely to be women than are non-resident degree recipients, who in turn are more likely to be women than are majority degree recipients. See Figure 41.

At the master's level, the ordering among the minority, non-resident, and majority recipients mirrors that of the bachelor's degree in almost every year. The trend among majority degrees is negative at alpha = .01 and the trend among minority degrees is negative at alpha = .10. The percentage of women receiving master's degrees among non-residents show no significant trend. See Figure 42.

There are too few doctoral degrees in information systems to do any analysis based on individual characteristics.

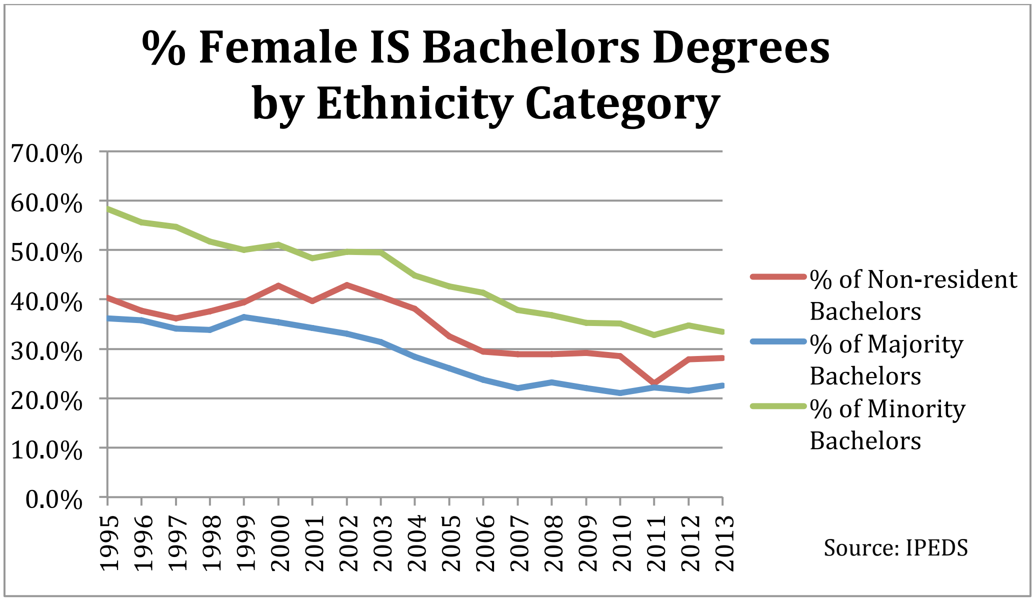


Figure 41. % Female IS Bachelor's Degrees by Ethnicity Category.

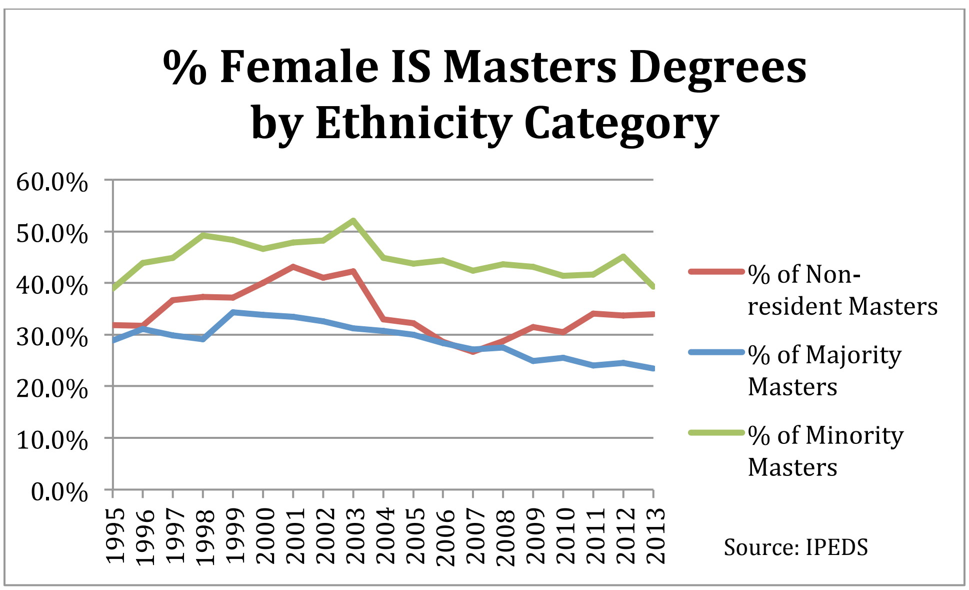


Figure 42. % Female IS Master's Degrees by Ethnicity Category.

## Information Technology

There is a negative trend in the percentage of information technology bachelor's degrees to women among both majorities and minorities, each significant at alpha = .01, and a negative trend for non-residents that is significant at alpha = .05. Minority bachelor's degree recipients are more likely to be women than are majority degree recipients. In general, the percentage of non-resident bachelor's recipients who are women falls in between the corresponding percentages for minority and majority recipients. See Figure 43.

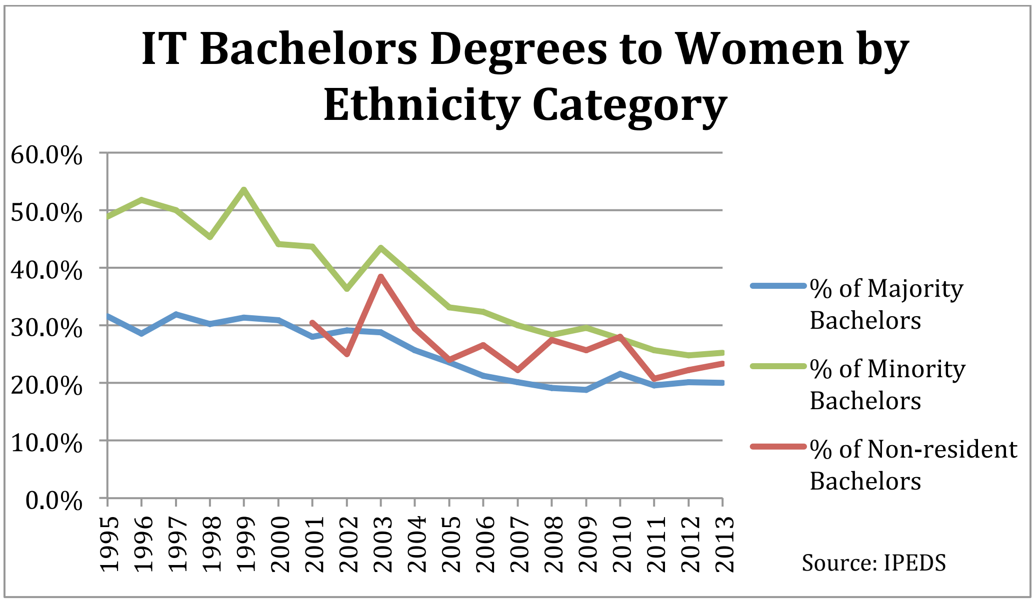


Figure 43. % Female IT Bachelor's Degrees by Ethnicity Category.

At the master's level, there is a negative trend in the percentage of degrees to women among minorities (alpha = .02), but no significant trend for non-residents or majorities. As was the case for bachelor's degrees, minority master's degree recipients are more likely to be women than are majority degree recipients, and the percentage of non-resident bachelor's recipients who are women tends to fall in between the corresponding percentages for minority and majority recipients. See Figure 44.

There are too few information technology doctoral degree recipients to do any analysis of individual characteristics.

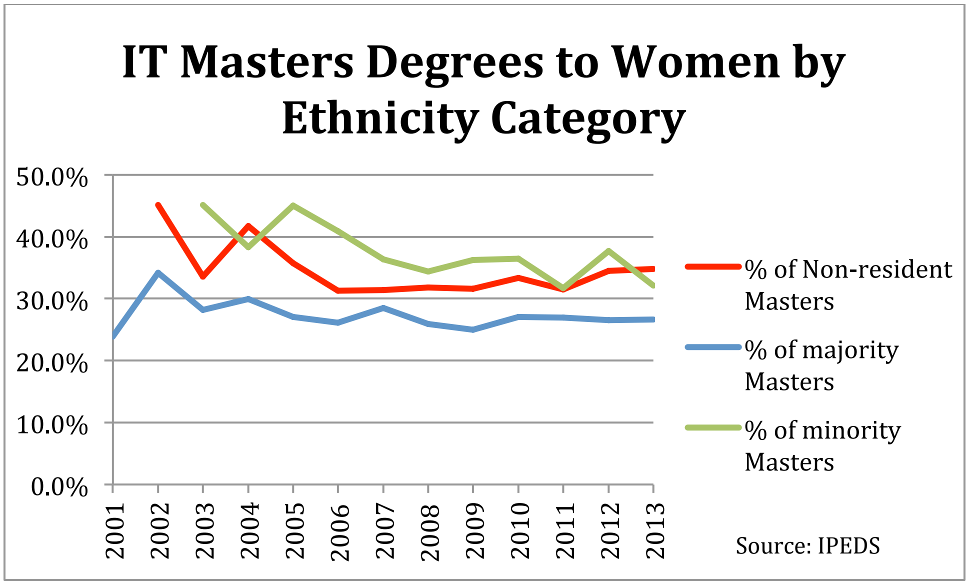


Figure 44. % Female IT Master's Degrees by Ethnicity Category.

## Information Science

As was the case for the information systems and computer science areas, the percentage of majority, minority, and non-resident bachelor's degrees in information science that were awarded to women each exhibits a negative trend, significant at alpha = .01. The declines are most pronounced for each group after 2004. Minority bachelor's degree recipients are more likely to be women than are non-resident degree recipients, who in turn are more likely to be women than are majority degree recipients; this ordering follows that in each of the other previous disciplines for which comparisons could be made at the bachelor's level. See Figure 45.

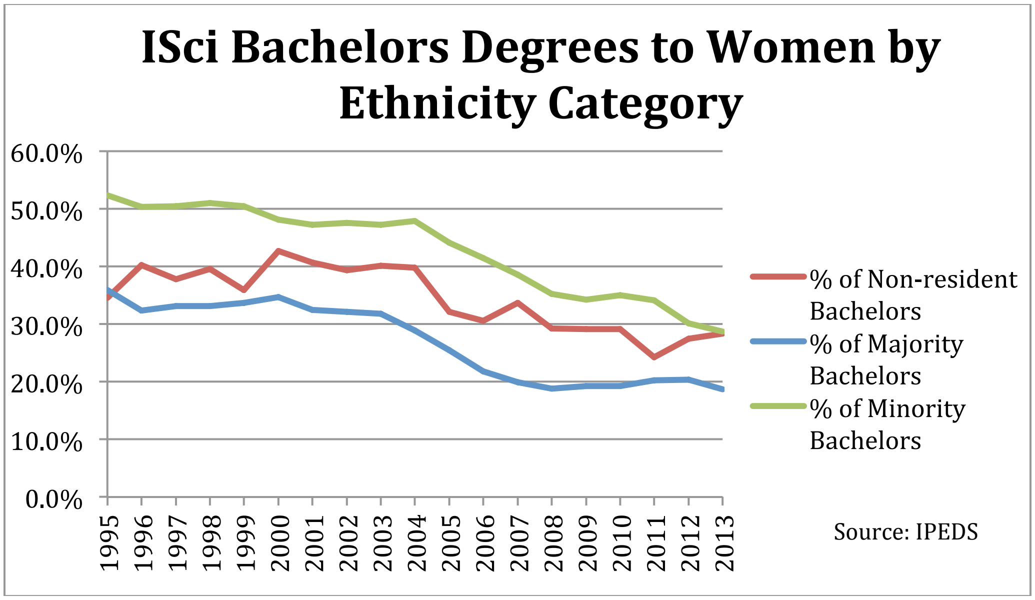


Figure 45. %F ISci Bachelor's Degrees by Ethnicity Category.

In the case of master's degrees (Figure 46), the percentage of minority and majority degrees that were awarded to women each exhibits a negative trend, significant at alpha = .01 and alpha = .10 respectively.  The trend with respect to degrees awarded to non-residents is not significant.  Minority master's degree recipients are more likely to be women than are majority or non-resident degree recipients.  There is no significant difference in the likelihood of non-resident recipients to be women relative to that of majority recipients.

There are an insufficient number of doctoral degrees in information science to do an analysis based on individual characteristics.

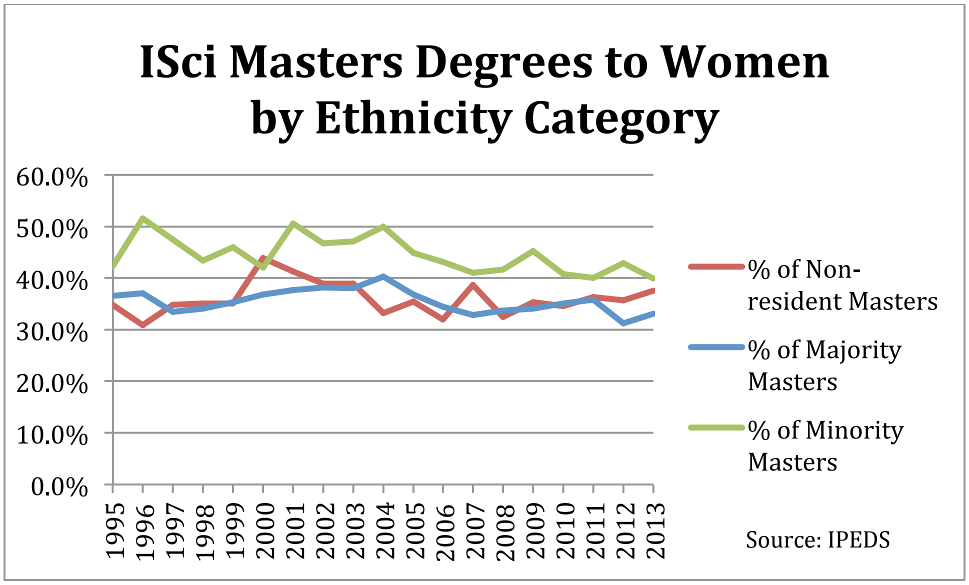


Figure 46. % F ISci Master's Degrees by Ethnicity Category.

## Security

There are no significant trends in the percentage of majority or minority bachelor's degrees in the security area that were awarded to women. Minority bachelor's degree recipients are more likely to be women than are majority degree recipients. See Figure 47.

No analysis of graduate degrees was possible due to the very small number of degrees awarded.

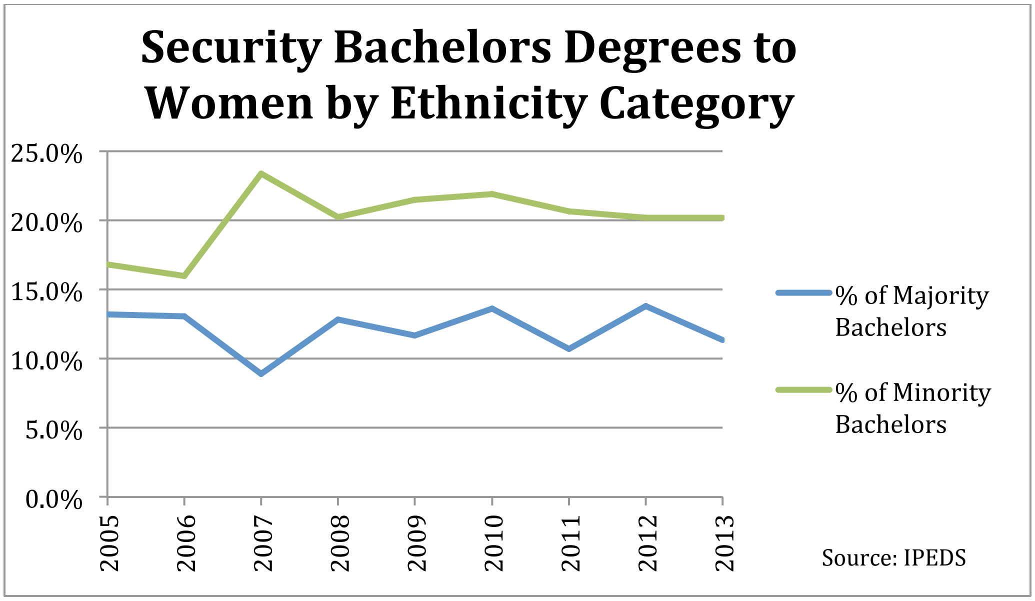

Figure 47. %F Security Bachelor's Degrees by Ethnicity Category.

## Interdisciplinary

The percentage of minority interdisciplinary bachelor's degrees that were awarded to women exhibits a negative trend, significant at alpha = .01. The corresponding bachelor's degree trends for majorities and non-residents each are not significant. Since the late 2000s, there appears to be an upward trajectory in both the minority and majority percentages. Non-resident bachelor's degree recipients are more likely to be women than are minority degree recipients, who in turn are more likely to be women than majority degree recipients. See Figure 48.

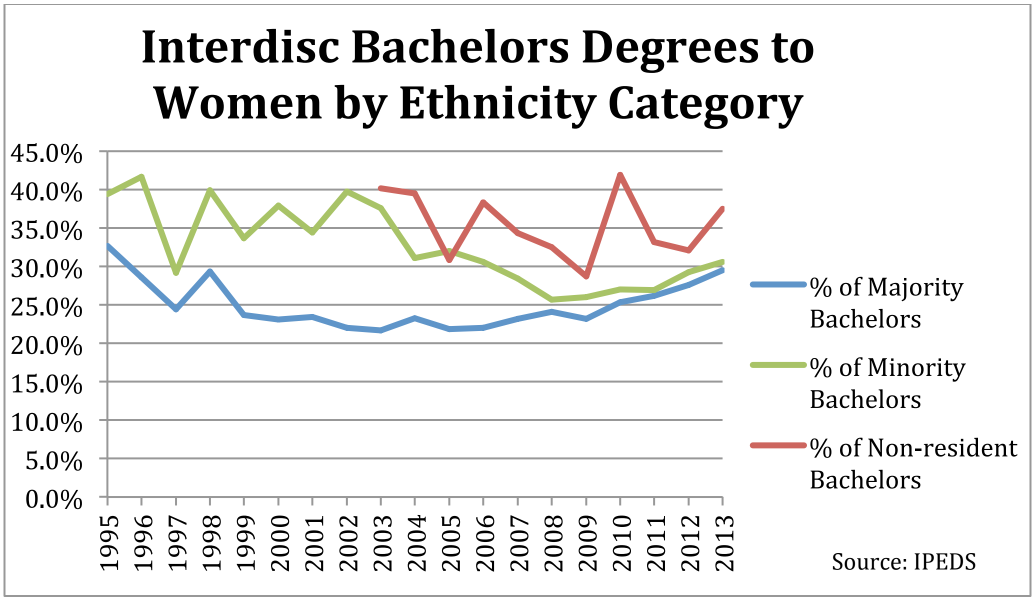


Figure 48. %F Interdisc Bachelor's Degrees by Ethnicity Category.

At the master's level, the percentage of interdisciplinary degrees awarded to women exhibits no significant trend for majorities or non-residents. For minorities, however, there is an increasing trend significant at alpha = .05. Minority master's degree recipients are more likely to be women than are majority degree recipients (alpha = .01). Non-resident master's degree recipients also are more likely to be women than are majority degree holders (alpha = .05). While the non-resident percentages have been fairly steady since 2004, both the majority and minority percentages have risen in the past few years (similar to the observation at the bachelor's level). See Figure 49.

There is an insufficient amount of doctoral degree data to do analyses with respect to individual characteristics.

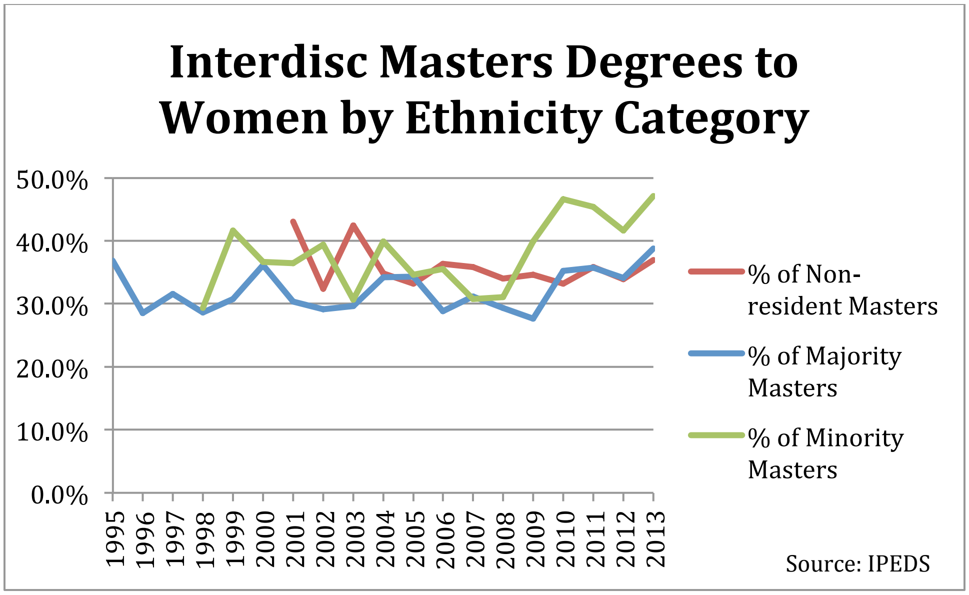


Figure 49. %F Interdisc Master's Degrees by Ethnicity Category.

## Synthesis of Results Based on Individual Characteristics

Table 9 shows the summary of the analyses based on individual characteristics. Where there were bachelor's trends in a given ethnicity category, they always were in the direction predicted (negative). At the master's level, there were several trends that were negative, but only among majorities and minorities, and in the interdisciplinary area, there was a positive trend for minorities. Non-resident master's trends were almost always not significant, though in computer science there was a positive trend.

In every discipline in which a comparison between minorities and majorities could be made, it was more likely that a minority bachelor's degree recipient would be female than that a majority recipient would be female. This is as hypothesized. The same is true for master's degree recipients.

In most disciplines in which a comparison could be made, whether at the bachelor's or master's level, it was more likely that a non-resident degree recipient would be female than that a majority degree recipient would be female. This is counter to our hypothesis of no difference.

## Table 9. IPEDS Data Analysis Based on Individual Characteristics.

| Analysis | CS | CE | SE | IS | IT | ISci | Sec | Idsc |
|---|---|---|---|---|---|---|---|---|
| BACHELOR's | | | | | | | | |
| Majority | ↓*** | ↓*** | ↓Ɨ | ↓*** | ↓*** | ↓*** | ↔ | ↔ |
| Minority | ↓*** | ↓*** | na | ↓*** | ↓*** | ↓*** | ↔ | ↓*** |
| Non-resident | ↓*** | ↔ | na | ↓*** | ↓* | ↓*** | na | ↔ |
| Minority: Majority | >*** | >*** | na | >*** | >*** | >*** | >*** | >*** |
| Non-resident: Majority | >*** | >*** | na | >*** | >*** | >*** | na | >*** |
| | | | | | | | | |
| MASTER'S | | | | | | | | |
| Majority | ↓*** | ↓*** | ↔ | ↓*** | ↔ | ↓Ɨ | ↔ | ↔ |
| Minority | ↓*** | ↓Ɨ | na | ↓Ɨ | ↓** | ↓*** | na | ↑* |
| Non-resident | ↑* | ↔ | ↔ | ↔ | ↔ | ↔ | na | ↔ |
| Minority: Majority | >*** | >Ɨ | na | >*** | >*** | >*** | na | >*** |
| Non-resident: Majority | >*** | >*** | ↔ | >*** | >*** | ↔ | na | >* |
| | | | | | | | | |
| DOCTORAL | | | | | | | | |
| Majority | ↔ | ↔ | na | na | na | na | na | na |
| Minority | na | na | na | na | na | na | na | na |
| Non-resident | ↑*** | ↑*** | na | na | na | na | na | na |
| Non-resident: Majority | >** | na | na | na | na | na | na | na |

Key for comparisons is the same as in Table 6.
Start years for comparison: CS 1990; CE 1995 except minority master's and minority: majority masters (2003); SE 2003; IS 1995; Isci 1995; Sec 2005
IT 1995 except non-resident bachelor's and majority master's (2001), non-resident master's (2002)
Idsc 1995 except non-res BS (2003), non-res MS (2001), minority MS (1998)

## Additional Analysis of Majorities

Our Majorities category consists of Whites and Resident Asians. While Whites comprise the preponderance of this category (e.g., of the 17,108 majority bachelor's graduates in CS in 2013 shown in Table 8, only 2,786 are Asian) and therefore are highly likely to exhibit the trend for overall majorities, we were interested to see if the trend for Asian women was similar. We again investigated the four largest disciplines (CS, IS, IT and Idsc) separately. We disaggregated both the bachelor's and master's majority data.

Figures 50 and 51 illustrate the results of the disaggregation for CS.

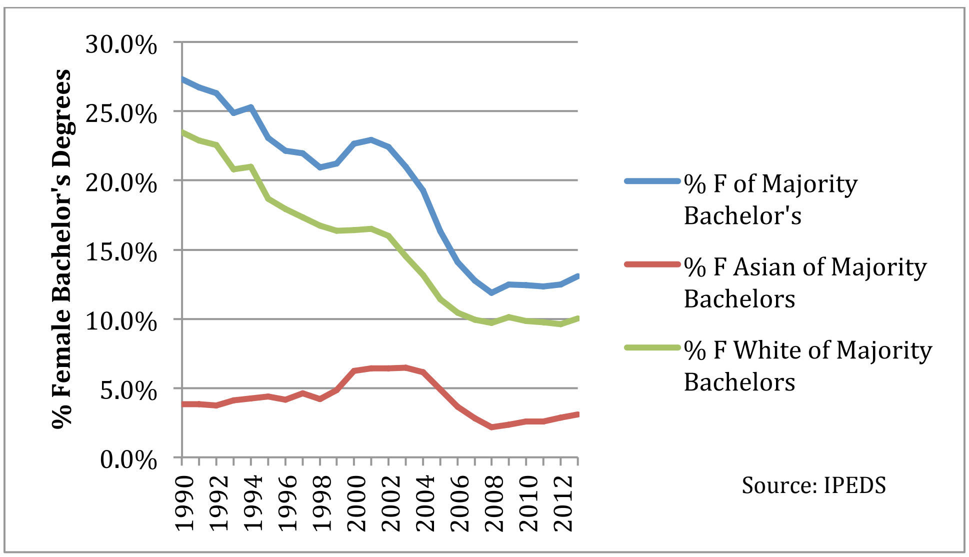


Figure 50. Asian vs. White Women Among Majority CS Bachelor's Degrees.

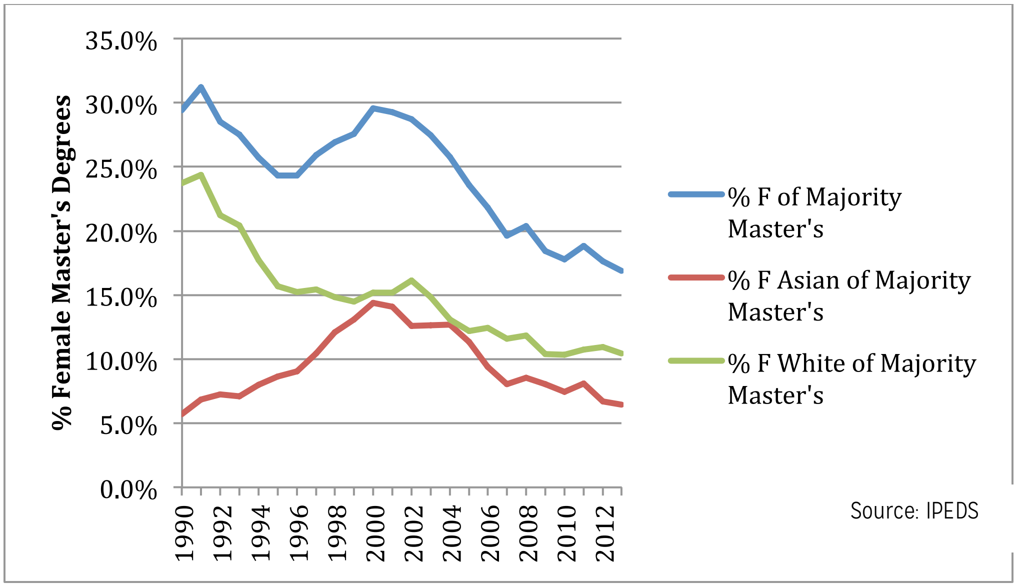


Figure 51. Asian vs. White Women Among Majority CS Master's Degrees.

As expected, for Whites, the trends mirror those for majorities as a whole; they are significantly negative at alpha = .01. However, the Asian bachelor's trend is negative, but significant only at alpha = .10. There was no significant change in the fraction of Asian women among majority master's degree holders. Note the increase in the fraction of majority master's degrees going to Asian women from the mid-90s through the early 2000s, followed by a decline since 2005. The fraction of majority master's degrees to White women, by contrast, has had no real growth period since 1990.

Table 10 summarizes the analyses for each of the four disciplines. Note that, in each case, the trends for Whites mirror that for all majorities, while in most cases, the trend for Asians is more favorable. The trends for Asians were not significant for IT bachelor's, CS master's and IS master's when those overall majority trends were significantly negative at alpha = .01. In the Idsc area, the fraction of majority master's degrees to Asian women increased significantly at alpha = .01, while there was no significant change in the fraction of majority master's degrees to women over all.

### Table 10. Trends for Asian vs. White Women Among Majority Degree Holders.

| Analysis | | CS | IS | IT | Idsc |
|---|---|---|---|---|---|
| Bachelor's | | | | | |
| All Majorities | | ↓*** | ↓*** | ↓*** | ↔ |
| Asian | | ↓Ɨ | ↓** | ↔ | ↔ |
| White | | ↓*** | ↓*** | ↓*** | ↔ |
| | | | | | |
| Master's | | | | | |
| All Majorities | | ↓*** | ↓*** | ↔ | ↔ |
| Asian | | ↔ | ↔ | ↔ | ↑*** |
| White | | ↓*** | ↓*** | ↔ | ↔ |

First year for analyses: CS 1990; IS and IDsc 1995; IT BS 1995, MS 2001
Key is the same as for Table 3.

## Additional Analysis of Minorities

The vast majority of persons from the Minorities category are Blacks or Hispanics. We were interested to see if there are differences in the trends for these two individual categories of minority female graduates within the four disciplines of CS, IS, IT and Idsc. We did this analysis only at the bachelor's level, where there is sufficient data across all years for all four disciplines.

The results are shown in Table 11. With the exception of the Idsc area, there were no differences between Black and Hispanic trends nor any difference from the overall minority trend. However, the Idsc area showed a difference in both Black and Hispanic trends from the overall minority trend. The overall minority trend was negative, significant at alpha = .01. While the Black trend still was negative, its significance level was only .02. The Hispanic trend was not significant. Fig. 52 shows the trend lines that gave rise to this unusual set of significance tests in the Interdisciplinary area. Of interest is the rise in Hispanic women's fraction of all minority bachelor's degrees since 2006, while the fraction of Black women among minority bachelor's degrees declined sharply during the late 2000s and has remained at this lower level.

Table 11. Trends for Black vs. Hispanic Women Among Minority Degree Holders.

| Analysis | CS | IS | IT | Idsc |
|---|---|---|---|---|
| Bachelor's | | | | |
| All Minorities | ↓*** | ↓*** | ↓*** | ↓*** |
| Black | ↓*** | ↓*** | ↓*** | ↓** |
| Hispanic | ↓*** | ↓*** | ↓*** | ↔ |

First year of analyses: CS 1990; IS, IT and Idsc 1995

Key is the same as for Table 3.

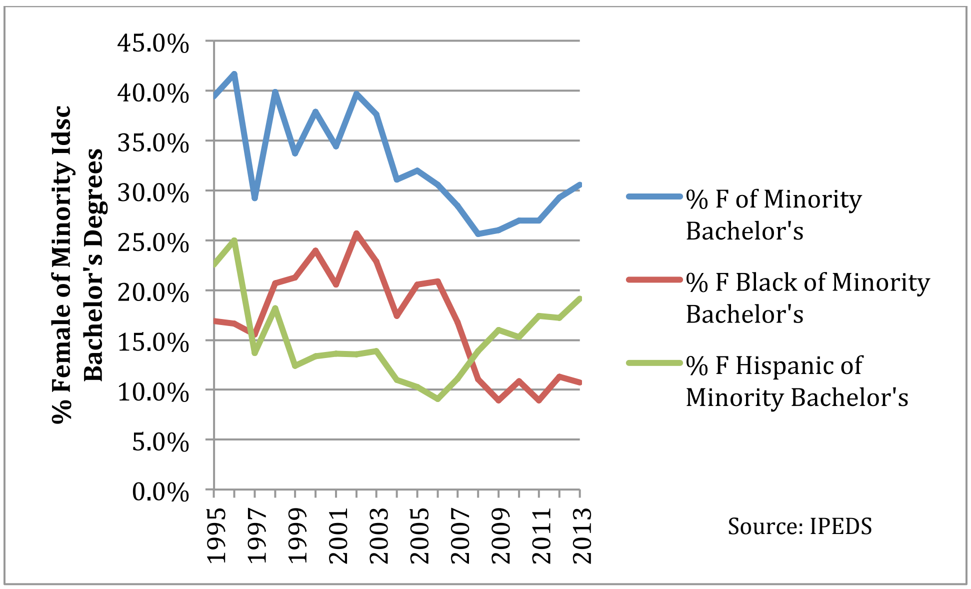


Figure 52. Black vs. Hispanic Women Among Minority Interdisciplinary Bachelor's Degrees.

## Doctoral Education Process

This portion of the results section looks at characteristics of students and institutions during the students' graduate education.

### *Baccalaureate Origins of New PhDs*

The SED includes information on the baccalaureate institution of each respondent. Fig. 53 shows, of those whose origin is each type of baccalaureate institution, what percent are female. For-profit institutions are omitted; a few doctoral recipients came from these institutions, but only a total of 37 over the period 1990-2013. There is substantial fluctuation from year to year; the figure groups data in 3-year bins to reduce the fluctuation. There is no clear trend except for the foreign institutions, from which there is a steady increase in the percent of women (alpha = .01). In general, the non-research institutions have a higher percentage of women than the research institutions. This is consistent with what we observed in Table 6, IPEDS Analysis Based on Institutional Characteristics. Fig. 53 also shows that public research institutions had a higher percentage of women than did private research institutions. This is in contrast with the overall comparison for most disciplines, as reported in Table 6, which showed private NFP institutions graduating a greater proportion of women than did public institutions.

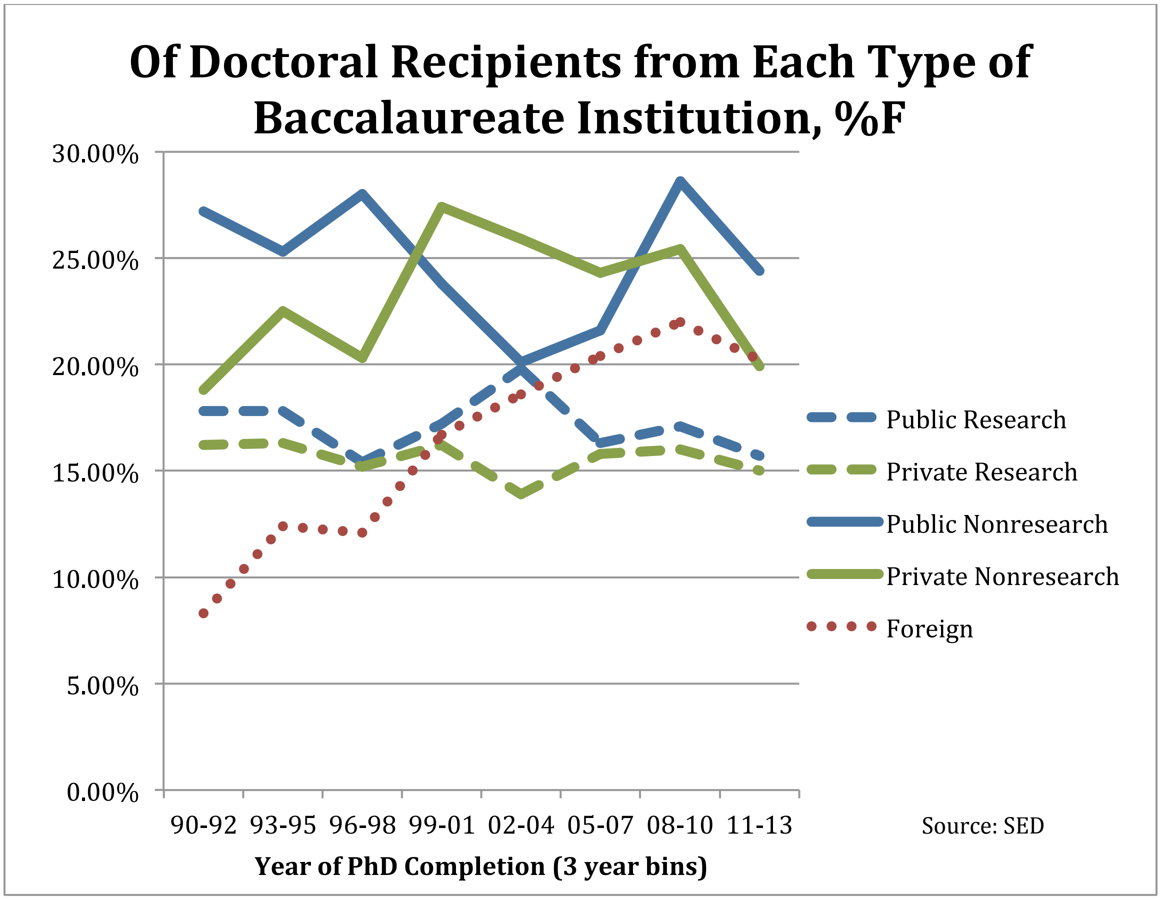


Figure 53. %F of Doctoral Recipients by Type of Baccalaureate Institution.

Fig 54 looks at the same data from a different direction. It asks, of the women who received a PhD in each year, what fraction came from each type of baccalaureate institution? In this view, the increasing role of foreign institutions as the baccalaureate source for women PhDs is even clearer, dwarfing the differences between types of domestic institutions. Within the domestic institutions, the public research institutions consistently are the largest source of women PhDs. Although women have been a smaller percent of the baccalaureate recipients from these institutions than they have been from non-research institutions, because these departments are larger on average, they produce larger total numbers of women who continue to a PhD.

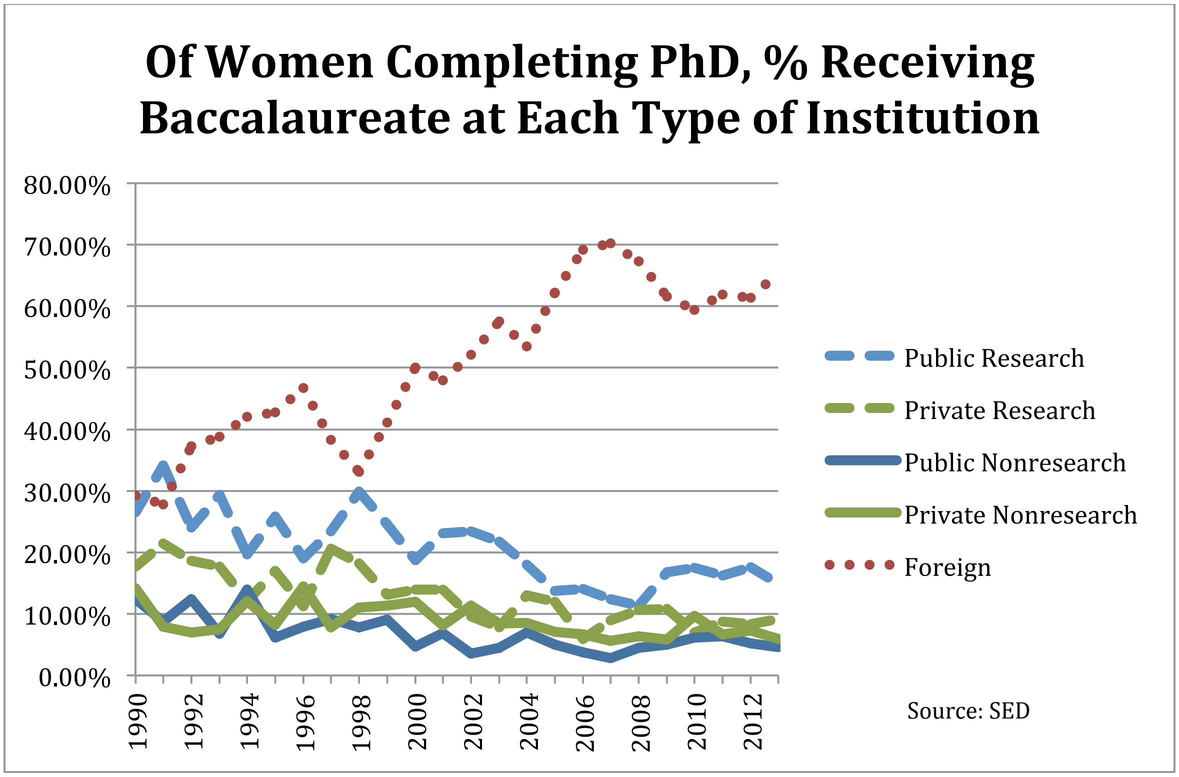


Figure 54. Of Women Completing PhD, % From Each Type of Baccalaureate Institution.

For comparison, figure 55 compares the percent of male and female doctoral recipients whose baccalaureate degrees came from foreign institutions. This demonstrates that the increase in women from foreign is not simply proportional to an overall increase in foreign students. The increase in the percent of foreign baccalaureates among PhD recipients has increased significantly for both genders (alpha = .01 for each) but, as the graph illustrates, there has been greater increase in this percentage among women.

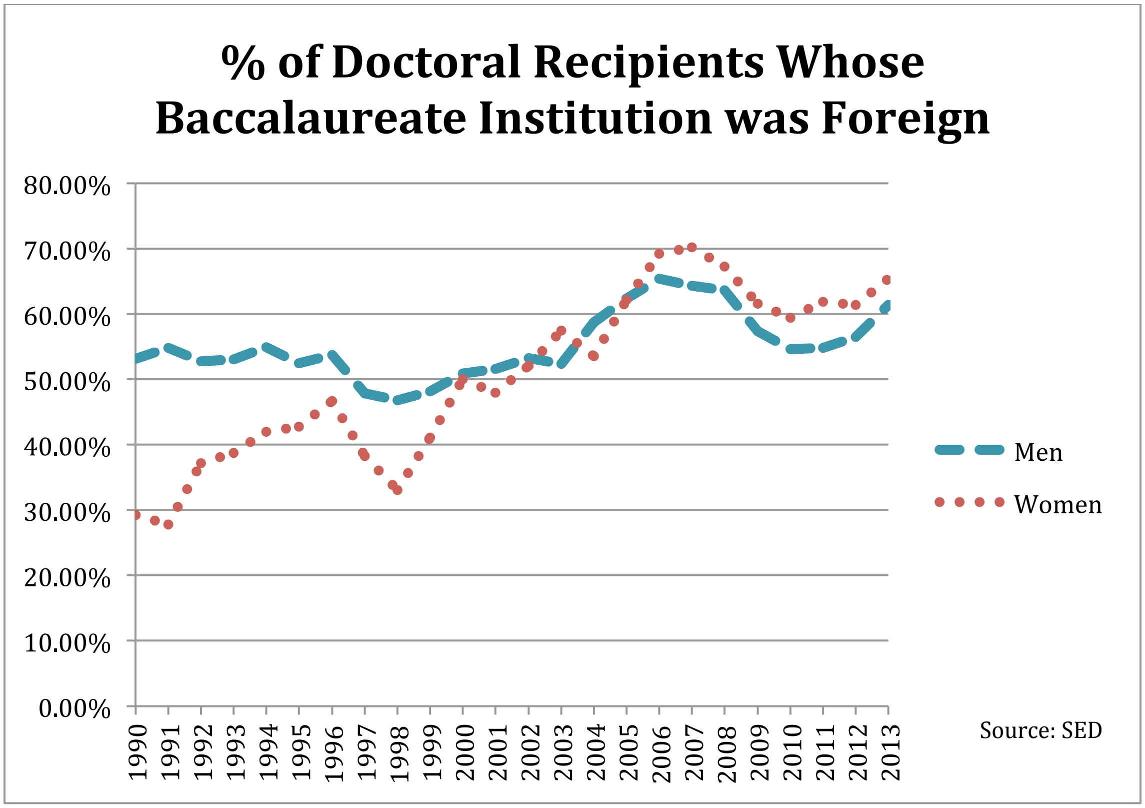


Figure 55. % of Doctoral Recipients Whose Baccalaureate was Foreign, by Gender.

The growing representation of foreign institutions as the baccalaureate origin of women PhDs parallels the growth in fraction of PhDs to women that are granted to temporary residents, as observed in Figure 36 for CS or in Table 9 in summary. Because the growth in foreign students is so strong, we were also interested in the source of these students by country or geographic region.

Fig 56 shows, among PhD recipients who earned their baccalaureate in selected geographic areas, the percent who are women. (This does not necessarily reflect the citizenship of the student.) The areas were selected as those with 5% or more of the total PhD recipients (male and female) who earned US doctorates in the period 1990-2013. Because of fluctuation from year to year, the figure shows data grouped into three-year bins.

There are significantly increasing percentages of women from India, the Middle East, and South Korea (alpha =.01 for each). There also is an increasing percentage of women from China (p=.06). Both China and South Korea showed a downturn in percent of women in 2011-2013. From 1990 – 2013 there was no significant change in the percentage of women among PhD recipients who earned their baccalaureate in the US.

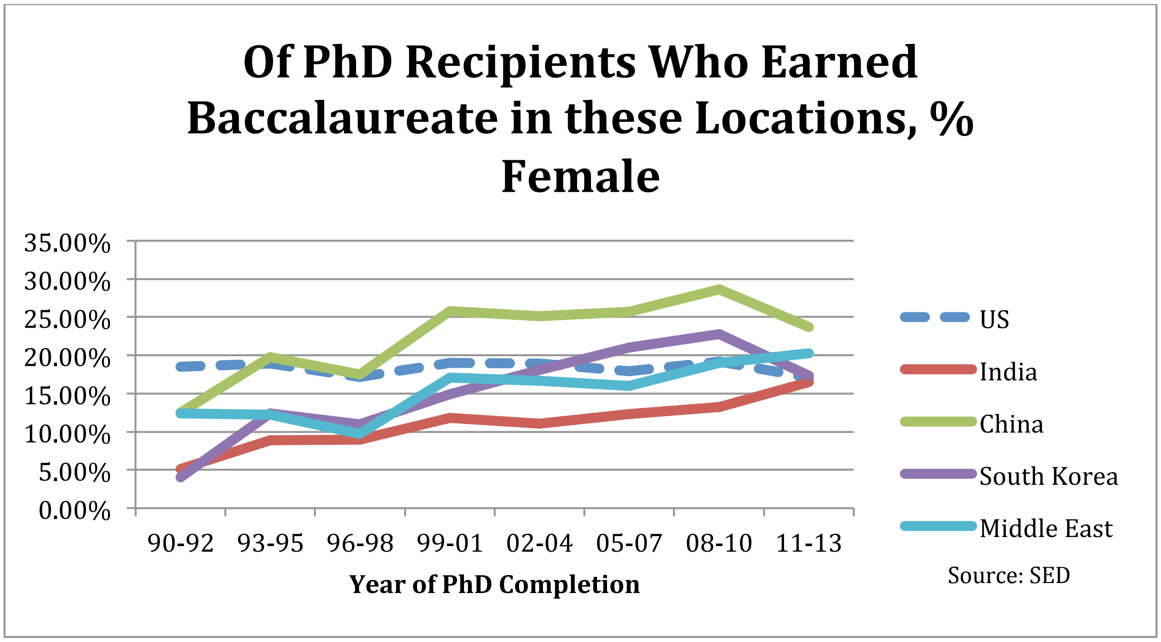


Figure 56. %F of PhD Recipients Who Earned Baccalaureate in Countries or Regions.

*CS Doctoral Enrollment (hypothesis: positive trend)*

Figure 57 shows the trend for women enrolled in CS doctoral programs. Consistent with our hypothesis, the graph shows a positive trend, though only significant at alpha = .10.

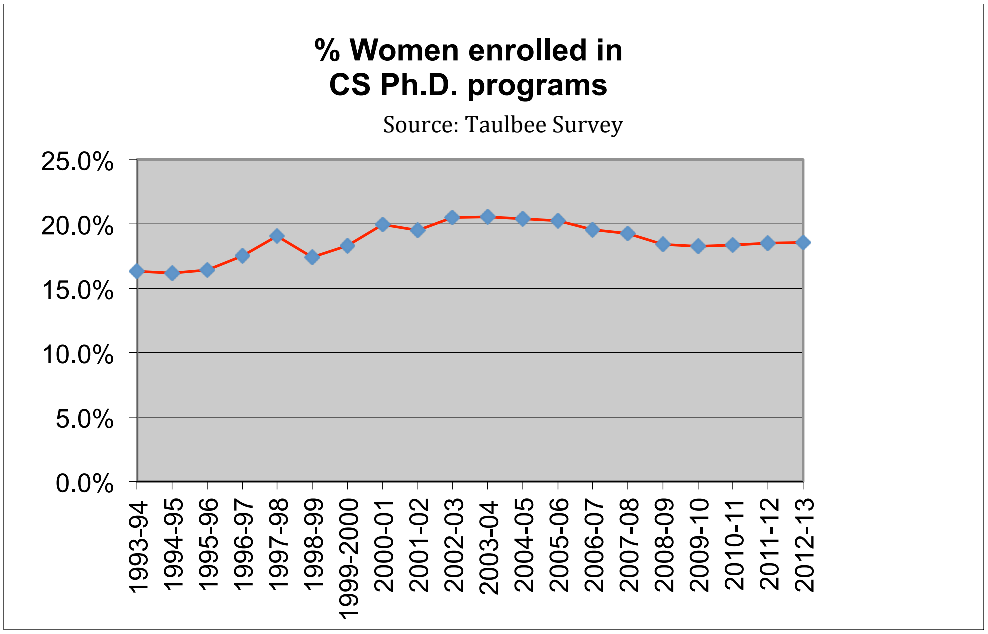


Figure 57. % Women Enrolled in CS Ph.D. Programs

We also are interested in comparing female doctoral enrollment percentages against subsequent percentages of doctoral degrees awarded. Since the enrollment figures only were available from Taulbee Survey data, we use the degree data published by the Taulbee Survey for this comparison.

The doctoral enrollment figures in a given year comprise students who are in their first year of the program and those who have been in the program for several years. To make a reasonable comparison of this aggregation of enrollment with degrees awarded, the year in which the degree is awarded should be later than the year for which the enrollment data is taken. As noted later in this report in the section on Time to Degree, in 2013, the median years to doctoral degree in computing, measured from time of first graduate entry, was (from shortest to longest) 7.1 (female temporary residents), 7.3 (male temporary residents), 7.6 (male majority), 8.0 (male URM), 8.9 (female majority), and 10.7 (female URM). Thus, the enrollment figures are roughly three to four years off the expected graduation year.

In the following figure, we offset the degree year by four from the enrollment year. That is, we used enrollment years 1990-2009 and graduation years 1994-2013 for the respective comparison pairs. The results were the same when the offset was three years.

There is a significant positive correlation (alpha = .01) between female enrollment percentage and subsequent awarding of the doctoral degree to women. Also, the percentage of women enrolled is significantly greater than the subsequent percentage of degrees awarded to women. This suggests there is differential attrition during the doctoral program based on gender, although some of the difference may be due to domestic women's longer time in the degree program.

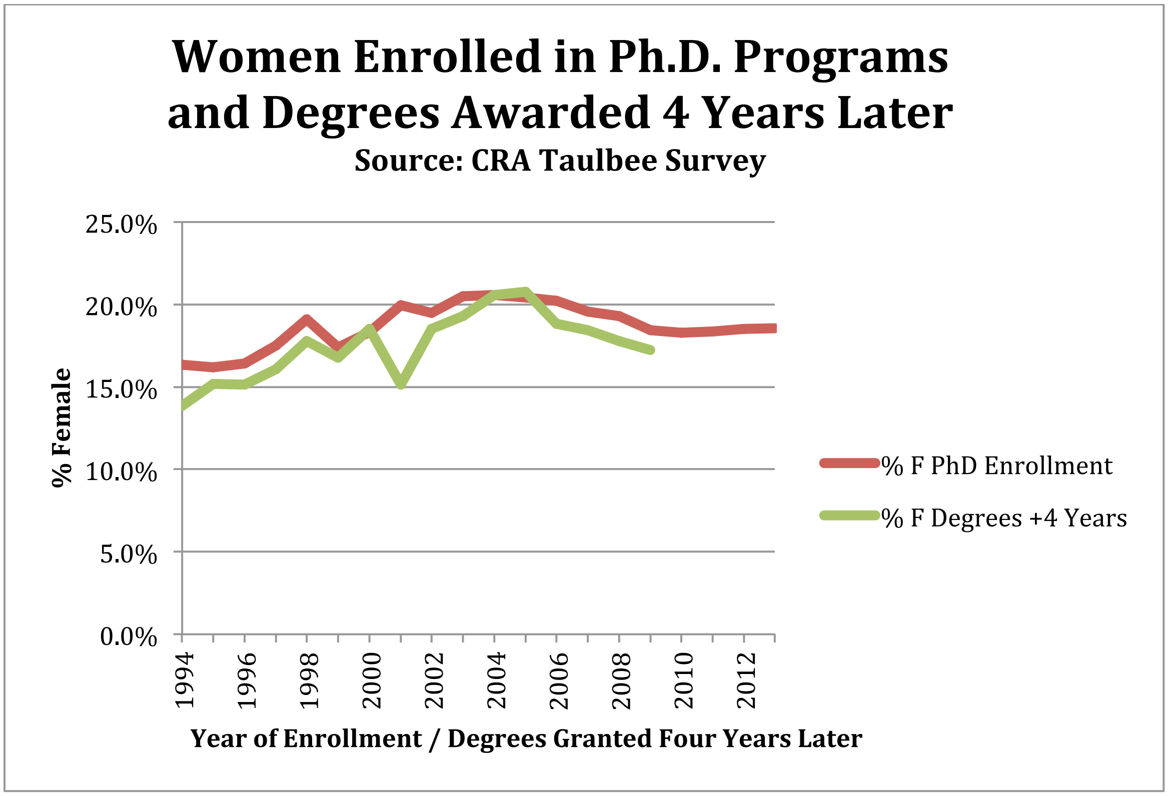


Figure 58. % Women Enrolled in Ph.D. Programs and Degrees Awarded 4 Years Later.

### *Relationship of Female Representation among Faculty to Female Representation among Students*

In discussions of department climate, there is an expectation that female faculty are important as role models and mentors to female students (Bonetta, 2010), although there is mixed evidence in some studies (Bettinger & Long, 2005). Further, it seems reasonable to assume that, whichever way the causation may run, departments that are more welcoming to women faculty will also be more welcoming to women students.

While we did not have sufficient data to look at trends, our Taulbee data allowed us to compare the percent of women faculty in a department with the percent of women students in the same department at a few points in time. We computed the nonparametric (Spearman) correlations for 2004, 2008, and 2013 between the percent of tenure track faculty who are women, the percent of baccalaureate recipients who are women, and the percent of PhD recipients who are women (overall for all years and separately for nonresident and domestic women in 2008 and 2013). The nonresident and domestic percentages are computed as the percent of all PhD recipients from the department who are nonresident women and the percent of all who are domestic women.

Table 12 shows the correlations. The following pairs of PhD variables have a positive correlation that is an artifact of their computation because the variables overlap in composition: percent of PhD recipients who are female to percent of PhD recipients who are resident female and to percent of PhD recipients who are nonresident female, and percent of nonresident PhD recipients in total to percent of PhD recipients who are nonresident women. Similarly, the negative correlation between the percent of PhD recipients who are resident women and the percent who are nonresident women is an artifact.

The strongest correlations are between the same variables over time, with stronger correlations between closer time periods and weaker ones between more distant times, indicating both stability and gradual change in each department's standing in terms of its percent of women. For faculty, each year's percent of women is not independent of the previous year, since the specific individuals on the faculty change slowly. For degrees awarded, however, degrees are not awarded to the same individuals in successive years. Significant year-to-year correlations for percent female baccalaureates and percent female PhDs then indicate consistencies in recruitment and/or retention of women in the departments.

As expected, then, the percent of female faculty correlates most strongly across time, while the percent of female baccalaureate recipients correlates across time but less strongly than faculty.

Table 12. Correlations Between %F Faculty and %F Students. Source: Taulbee Survey.

| | 2013 | | | | | | 2008 | | | | | | 2004 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ttrk %f | Ba %f | Pa %f | Pa %resf | Pa %non-resf | Pa %non res | Ttrk %f | Ba %f | Pa %f | Pa %resf | Pa %non-resf | Pa %non res | Ttrk %f | Ba %f | Pa %f |
| TTrk%f 13 | -- | .19* | .28** | .35** | .10 | -.06 | .54** | .17* | .12 | .17* | .13 | -.07 | .35** | .19* | .08 |
| Ba%f 13 | .19* | -- | -.00 | .14 | -.09 | -.07 | .06 | .35** | .11 | .09 | .14 | -.10 | .02 | .29** | .11 |
| Pa%f 13 | .28** | -.00 | -- | .64** | .65** | .13 | .04 | -.09 | -.02 | .06 | .03 | .04 | .00 | -.02 | .07 |
| Pa%resf 13 | .35** | .14 | .64** | -- | -.04 | -.23** | .12 | .12 | -.01 | .18* | -.11 | -.12 | .12 | .21* | -.00 |
| Pa%nonresf 13 | .10 | -.09 | .65** | -.04 | -- | .48** | -.07 | -.24** | .00 | -.08 | .19* | .11 | -.10 | -.15 | .05 |
| Pa%nonres 13 | -.06 | -.07 | .13 | -.23** | .48** | -- | -.12 | -.19* | .07 | -.12 | .31** | .28** | -.18* | -.04 | -.04 |
| Ttrk%f 08 | .54** | .06 | .04 | .12 | -.07 | -.12 | -- | .16 | .06 | .10 | -.06 | -.11 | .66** | .14 | .12 |
| Ba%f 08 | .17* | .35** | -0.09 | 0.12 | -.24** | -.19* | .16ˆ | -- | -.02 | .07 | -.08 | -.16 | .06 | .35** | .01 |
| Pa%f 08 | .12 | .11 | -.02 | -.01 | .00 | .07 | .06 | -.02 | -- | .63** | .58** | .06 | .00 | .11 | -.00 |
| Pa%resf 08 | .17* | .09 | .06 | .18* | -.08 | -.12 | .10 | .07 | .63** | -- | -.10 | -.34** | .01 | .08 | .02 |
| Pa%nonresf 08 | .13 | .14 | .03 | -0.11 | .19* | .31** | -.06 | -.08 | .58** | -.10 | -- | .51** | -.05 | .09 | .06 |
| Pa%nonres 08 | -.07 | -.10 | .04 | -.12 | .11 | .28** | -.11 | -.16 | .06 | -.34** | .51** | -- | -.01 | -.10 | .06 |
| Ttrk%f 04 | .35** | .02 | .00 | 0.12 | -.10 | -.18* | .66** | .06 | .00 | .01 | -.05 | -.01 | -- | .07 | -.02 |
| Ba%f 04 | .19* | .29** | -.02 | .21* | -.15 | -.04 | .14 | .35** | .11 | .08 | .09 | -.10 | .07 | -- | -.01 |
| Pa%f 04 | .08 | .11 | .07 | -.00 | .05 | -.04 | .12 | .00 | -.00 | .02 | .06 | .06 | -.02 | -.01 | -- |

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
ˆ Correlation is signicant at the 0.10 level (2-tailed).

The correlates of percent of female PhD recipients differ between nonresident women and domestic women.  In 2013, the percent of PhD recipients who are domestic women correlates significantly with the percent of tenture track faculty who are women, and with the percent of baccalaureate recipients who were female in 2004 (but not 2008).

### *Funding for Doctoral Study*

Fig. 59 shows the percent of each gender whose primary source of doctoral funding was a research assistantship, teaching assistantship, graduate fellowship or dissertation fellowship, or own resources. Other sources of funding in the SED data include foreign government, employer, and other; few students were funded by these mechanisms.

Funding data trends are examined from 1998-2013 because of a change in the way the data was collected and coded in 1998.

The percent of both men and women who fund their doctoral studies primarily through a research assistantship increased steadily over the time period, but a higher percentage of males than females fund their studies this way. Conversely, the percent of those funding their doctoral studies with their own resources has decreased steadily, but a higher percentage of females than males fund their studies this way.

For men, there is a significant increasing trend in the percent funding their studies through a fellowship; the trend is not significant for women. There is no significant trend in TA funding for either men or women.

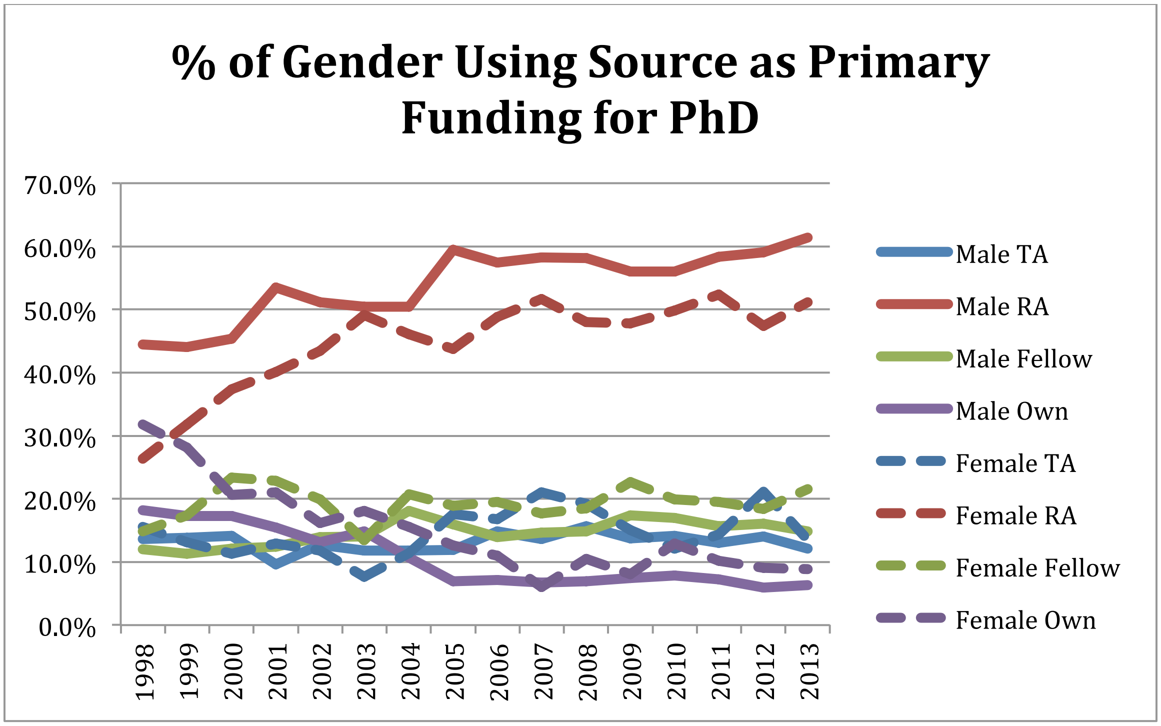


Figure 59. % of Gender Using Source as Primary Funding for PhD

Foreign and domestic students have somewhat different sources of funding. Figure 60 shows the main source of funding for students completing their degree in 2013, by gender/residency groups. Male and female foreign students have very similar patterns of TA and RA funding, but some males also had government or own resource funding while females did not. Employer funding and own resource funding are more likely and TA funding less likely for domestic students, both male and female, than for foreign students. Thus, the fact that a higher percentage of women than men use their own funds for their doctoral study is totally due to domestic students. Finally, domestic women are as likely to have fellowship funding as RA funding, the only group for which this is true. In theory fellowship funding, with its absence of a work requirement, is a positive thing, particularly in the final year of dissertation completion (Mwenda, 2010). However, some research has indicated that persistence among underrepresented doctoral students depends on how well integrated they are into their academic communities (Herzig, 2004). Thus RA funding, which is more likely to engage students immediately in a research group, may be less isolating.

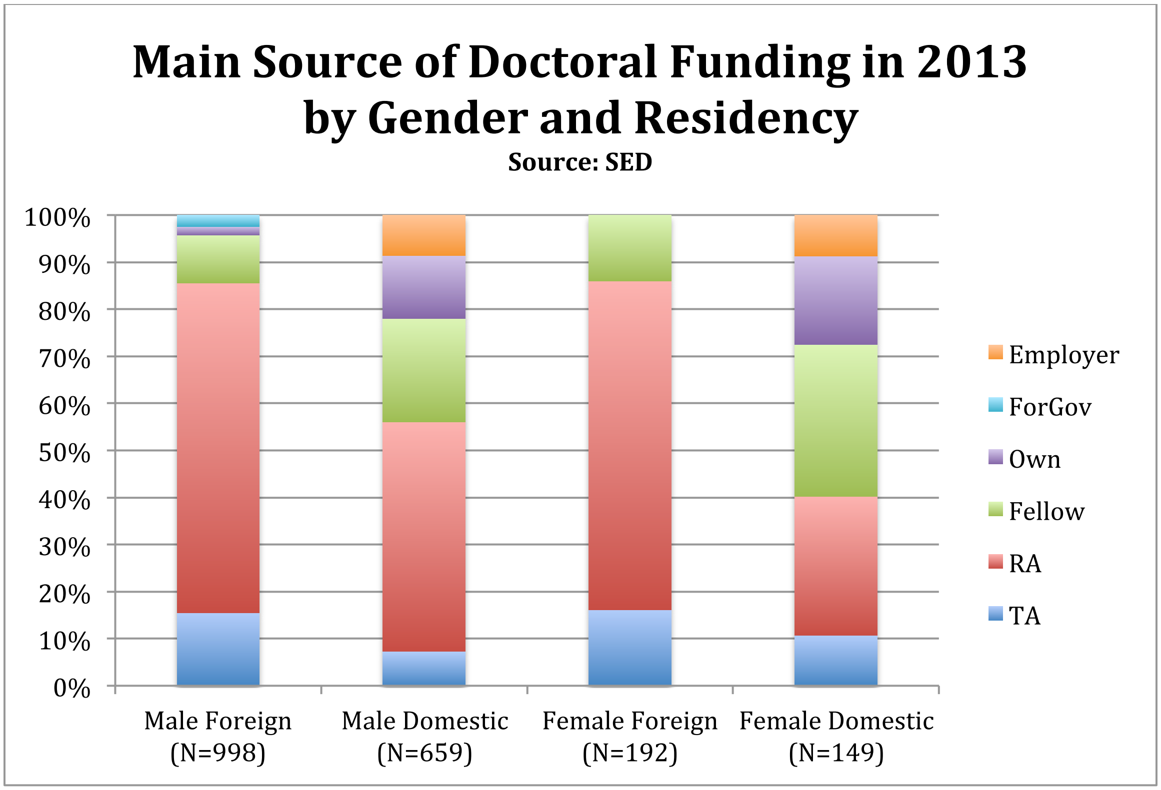


Figure 60. Main Source of Doctoral Funding in 2013 by Gender and Residency.

### *Time to Degree*

SED includes information on the time to degree from first graduate entry, years spent in graduate coursework, and years spent on dissertation. Figure 61 shows the median time to degree by gender/ethnicity/citizenship group. Female URM data is omitted before 2007 because there are fewer than 10 data points per year in 2004 and 2006.

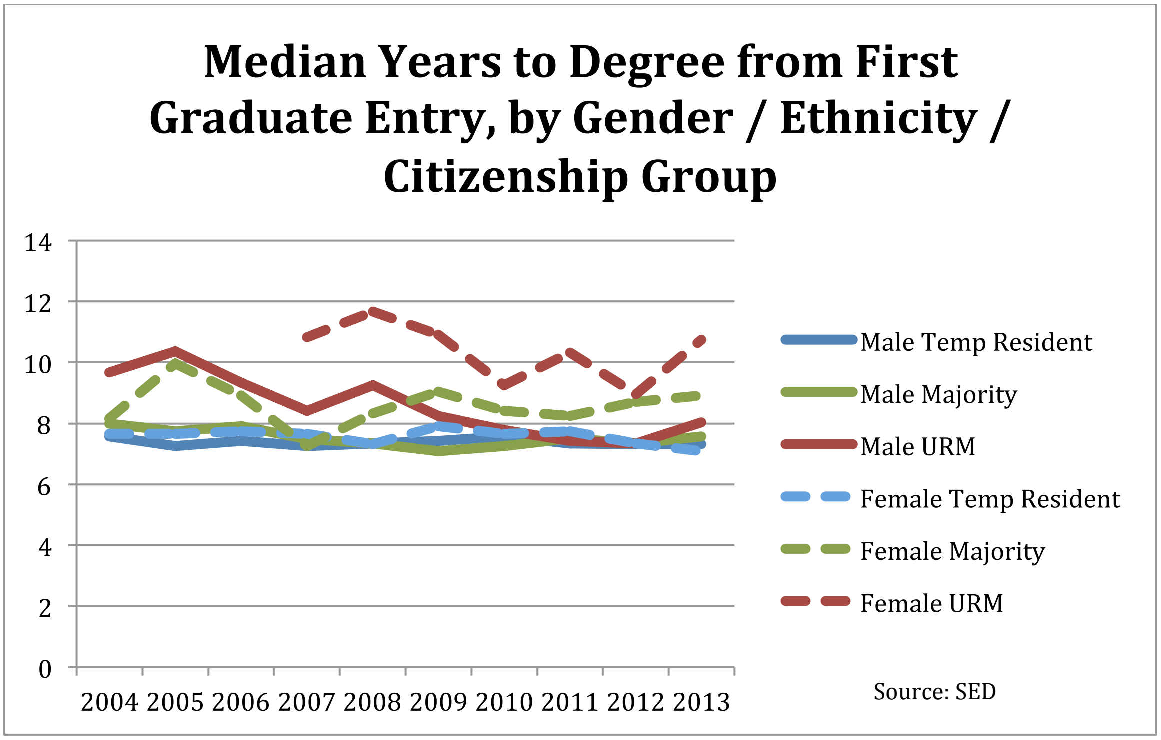


Figure 61. Median Years to Degree From First Graduate Entry by Gender/Ethnicity/Citizenship

Female URM students spend longer, on average, than other groups completing their PhD. In the earlier years, male URMs spent the second longest time, but they change places with female majority students in later years.

There are several possible explanations why domestic women (but not temporary resident women) might take longer to complete their degree.

- They may be more likely to begin (or even complete) graduate work in a different field and later complete a computing PhD
- They may take time off during their graduate studies, e.g., for maternity leave, to get a break between computing master's degree and a computing PhD, etc.
- They may spend longer than average on their doctoral coursework
- They may spend longer than average completing their dissertation

Table 13 looks at the median years spent on coursework, dissertation, and not working on the doctoral program after beginning it, by gender / ethnicity / citizenship group.  The overall median is 3 years on coursework and 3 years on dissertation; the coursework and dissertation columns show the number of years from 2004-2013 that students completing a degree had a group median different from 3. For the time spent not working on degree, the group medians are not useful because all are 0. Those columns, therefore, show the percent of the group who report time out from the degree program as 0 years, 1 year, or more than one year.

The results in Table 13 indicate that URM students of both genders are more likely to take more than the median 3 years to complete their doctoral coursework, but female URM students are more likely to take less than the median 3 years to complete their dissertation.  Temporary resident students of both genders are least likely to take time off during a degree program, while domestic women, especially URM women, are most likely (but still, more than three fourths of them do not take time off). Both additional coursework and time off during the degree program, then, are likely contributing factors to URM women's longer time to degree completion.

Table 13. Contributing Factors to Time to Degree Completion.

| Contributing Factors to Time to Degree Completion | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Coursework | | Dissertation | | Not Working on Degree | | |
| | Years group median < 3 | Years group median> 3 | Years group median < 3 | Years group median > 3 | % 0 years | % 1 year | % > 1 year |
| Male Temp Res | 3 | 0 | 0 | 0 | 89.8 | 7.4 | 2.8 |
| Male Majority | 0 | 0 | 0 | 0 | 84.7 | 9.4 | 5.9 |
| Male URM | 0 | 3 | 0 | 1 | 84.6 | 10.1 | 5.3 |
| Female Temp Res | 0 | 0 | 0 | 0 | 88.9 | 8.5 | 2.6 |
| Female Majority | 0 | 0 | 0 | 0 | 81.1 | 11.2 | 7.7 |
| Female URM | 0 | 4 | 3 | 0 | 77.1 | 11.9 | 11.0 |

## Postgraduation Study and Employment Plans

### *Postdoctoral Positions (hypothesis: no significant trend)*

Figure 62 illustrates the trend in the percentage of new post-doctorates that were women.  There are three data sources: SED data from the number of students who say their postgraduate plan is to be a postdoctorate, Taulbee data on the initial employment of new PhDs, and Taulbee data on the new postdocs hired by the doctoral granting departments that participate in the Taulbee Survey. There is no significant trend in the Taulbee data, consistent with our hypothesis. However, contrary to the hypothesis, the SED data (which covers a longer time frame and has less year-to-year fluctuation) shows an increasing trend in the percent of women, significant at .01.

There is a local peak in the percent of women postdocs in 2010-2011, especially noticeable in the Taulbee postdoc new hires, but the cause is uncertain. CRA, with support from the National Science Foundation, organized a Computing Innovation Fellowships (CI Fellows) program in 2009-2011 and included diversity as one of the selection criteria. The program supported 60 CI Fellows (40% female) who completed their degrees in 2009, 47 (32% female) in 2010, and 20 (25% female) in 2011. This represents a significant number of individuals who might not otherwise have received a postdoc, but the timing is not quite right to produce the peaks in the diagram.

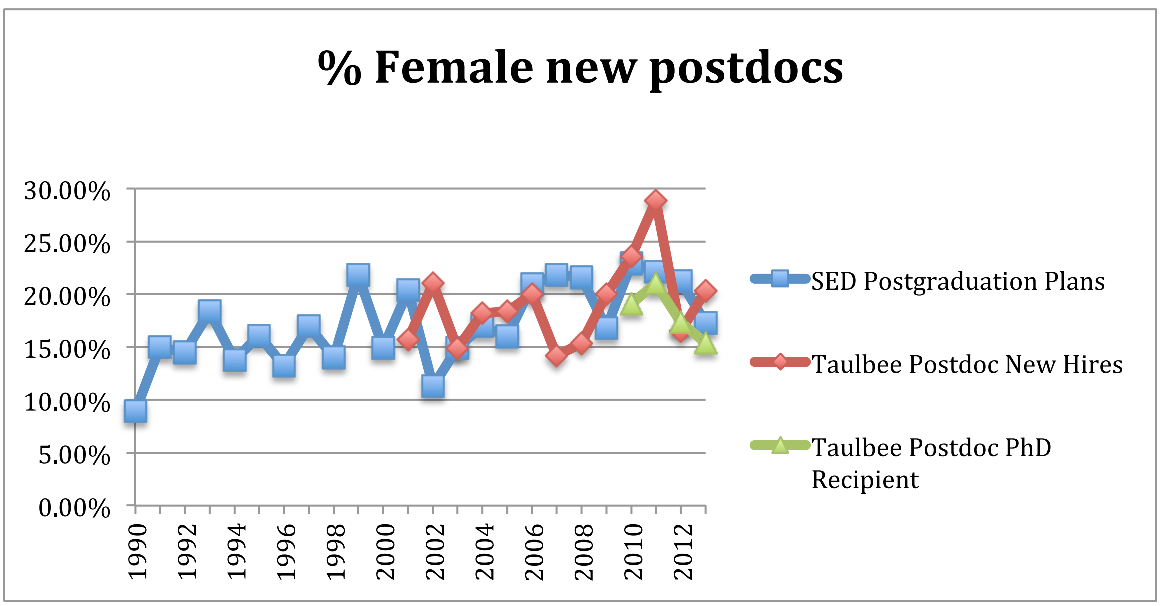


Figure 62. % Female New Postdocs

### *Postdoctoral Funding*

This analysis includes only respondents who intend a postdoc in the year following graduation and have a postdoc status of continuing with a predoctoral employer or another firm postdoctoral commitment for the next year.

Traditionally, postdocs have not been as common in computing as in other fields, particularly the life sciences. The total number of computing postdocs began to grow about 2004, but even then, there are few women reporting committed funding from most sources. Therefore, rather than look at trends, Figure 63 compares the totals of men and women receiving postdoctoral support from 2001-2013. While the funding source with the highest percent of women is private foundations and other nonprofits, by far the highest number of women are funded by a college or university, with the U.S. Government second.

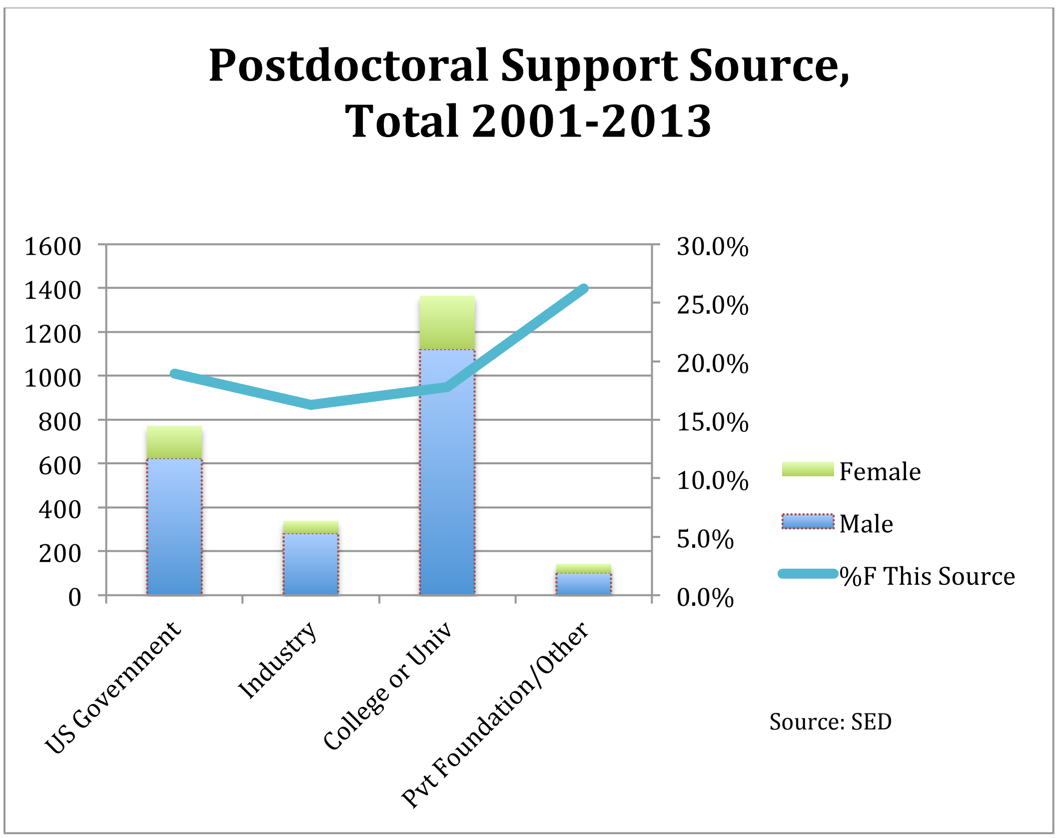


Figure 63. Postdoctoral Support Source, Total 2001-2013.

### *New Tenure-track Faculty Positions (hypothesis: positive trend)*

Figure 64 shows the trend in the percentage of new faculty who are women. We looked at two measures of new faculty: the Taulbee department reports of new tenure-track hires, and the SED report of new graduates' plans. In the Taulbee data there is a significant positive trend in the percentage of new tenure-track hires who are women (alpha = .01). In the SED, there is also a significant positive trend (alpha = .01) in the percentage of women among those whose postgraduation plans include taking a position in a 4-year college or university, medical schools, or academic-affiliated research institute. SED does not distinguish doctoral and nondoctoral institutions.

The SED reports a higher percentage of women going to academia than the Taulbee reports in faculty hiring at the doctoral institutions. This suggests that the nondoctoral institutions hire a higher proportion of women than do the doctoral institutions. The ACM NDC survey reported a similar fraction of new female hires in 2013-14 at nondoctoral institutions (22.9%) as did the Taulbee Survey (22.5%). But NDC also reported an overall greater percentage of female faculty at the assistant professor level than did Taulbee (29.3% vs. 26.3%). This lends further credence to the hypothesis that a greater proportion of new faculty hires at nondoctoral institutions are women compared with new hires at doctoral institutions. The Taulbee data also includes only tenure-track hires, while the SED does not differentiate; but Taulbee history suggests that in the non-tenure-track ranks, a higher percentage of women in teaching positions will be counterbalanced by a lower percentage of women in research faculty positions (in 2014, newly hired teaching faculty are 25.4% female and research faculty are 21.6% female).

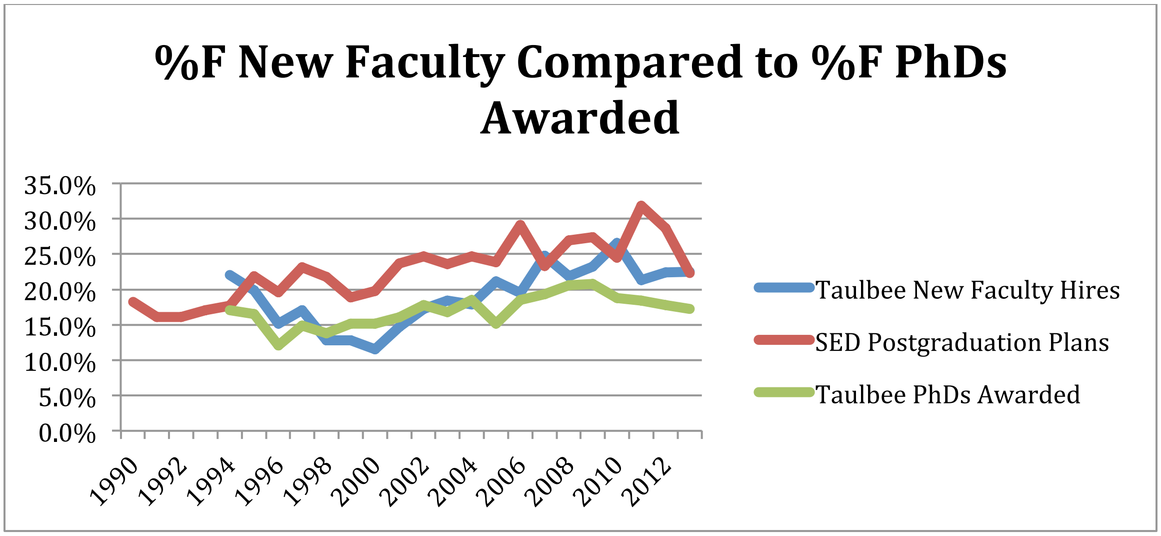


Figure 64. %F New Faculty Compared to %F PhDs Awarded.

Figure 64 also compares the percentage of women among new faculty hires in a given recruiting year with the percentage of female doctoral degree graduates in that year. Since the hiring information is only available from the Taulbee Survey, we used the doctoral degree production data from the Taulbee Survey for this comparison.

There is a significant positive correlation (alpha = .01) between the degree production percentages and the faculty hiring percentages. Furthermore, in most years a greater percentage of women have been among new female hires than among new doctoral graduates; the two trend lines are significantly different at alpha = .01. This suggests that there is not a loss in participation of women in doctoral program academic faculty at the transition from doctoral graduation.

Faculty hiring percentages from Taulbee correlate less strongly with the percent of SED respondents reporting postgraduation plans of academic employment (alpha =.10). This is probably due to the number of women taking academic positions at the nondoctoral institutions, which are not included in the Taulbee results.

### *Industry Positions*

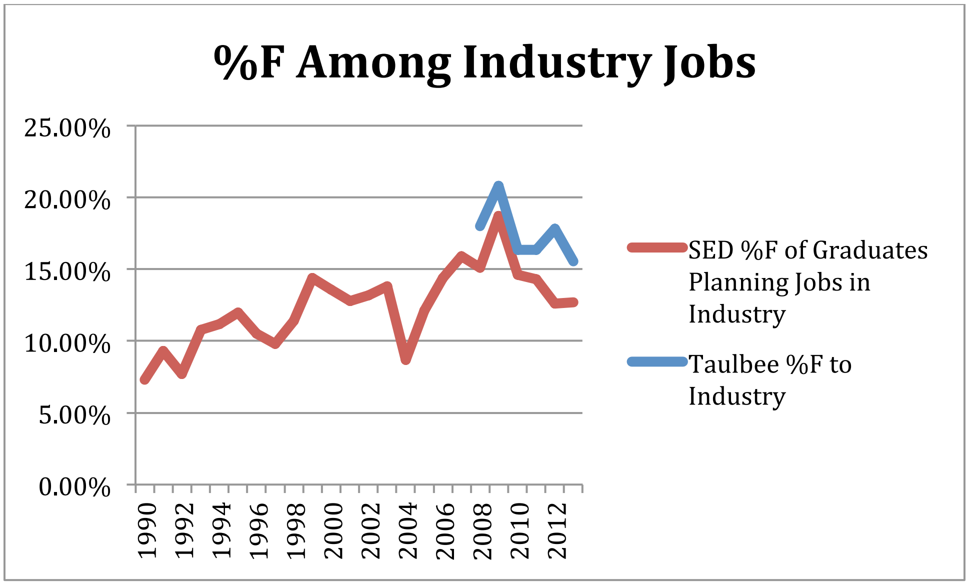


Figure 65. %F Among Industry Jobs

Fig 65 examines data from the SED. Of the people intending to work in industry, the percent female increased over 1990-2013, significant at .01. However, there has been a steady decrease since 2009. The trend in the Taulbee data, which covers a shorter time period, is not significant.

### *Overview of Postgraduation Plans of Doctoral Graduates by Gender*

Figure 66 summarizes the postgraduation plans by gender for 3-year bins, for those going to the three largest categories of postdoc, academia, or industry (graduates going to government or other are omitted from this chart). For both genders, the proportion going to a postdoc has increased and the proportion going direct to academia has decreased over time. Keep in mind that the stacked columns show proportion within gender and that the raw numbers of men are always higher; in the 11-13 year, for example, the proportion of women going to academia is substantially higher than the proportion of men, but this reflects 173 women and 457 men.

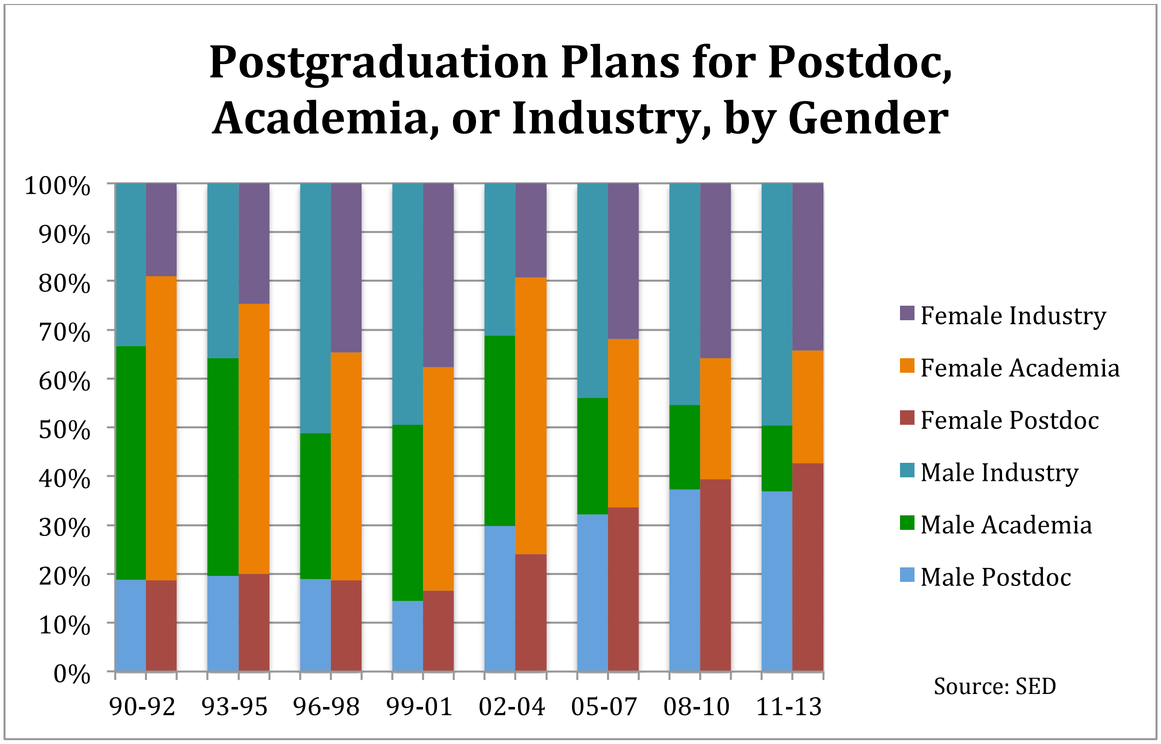


Figure 66. Postgraduation Plans for Postdoc, Academia, or Industry, by Gender.

### *Reported Starting Salaries*

The SED has collected anticipated salary information from respondents since 2008. Figure 67 shows the mean starting salary for those individuals whose postgraduation plans were definite (i.e., returning to /continuing predoctoral employment or had a definite commitment from an employer; those who were still negotiating or seeking are not included). The category of government is omitted because of low numbers overall. There is no significant trend in the postdoc or academia salaries; industry salaries have risen for both men and women. The male salary increase is significant at .05; the female increase has a strong correlation of .60 but is not significant due to the short time frame. Clearly, the type of employment accepted had a greater influence on salary than did gender. Women's salaries tended slightly below men's for each type of employment. The industry difference is significant at alpha=.10 and the others are not statistically significant, probably due to the short time frame. In addition, because industry salaries are higher than the other types and because women are less likely to have taken industry jobs, the male-female gap is higher for the average salary of all new PhDs than it is within any one employment type. Over the six years, the average woman's starting salary was 93.5% of the average man's starting salary.

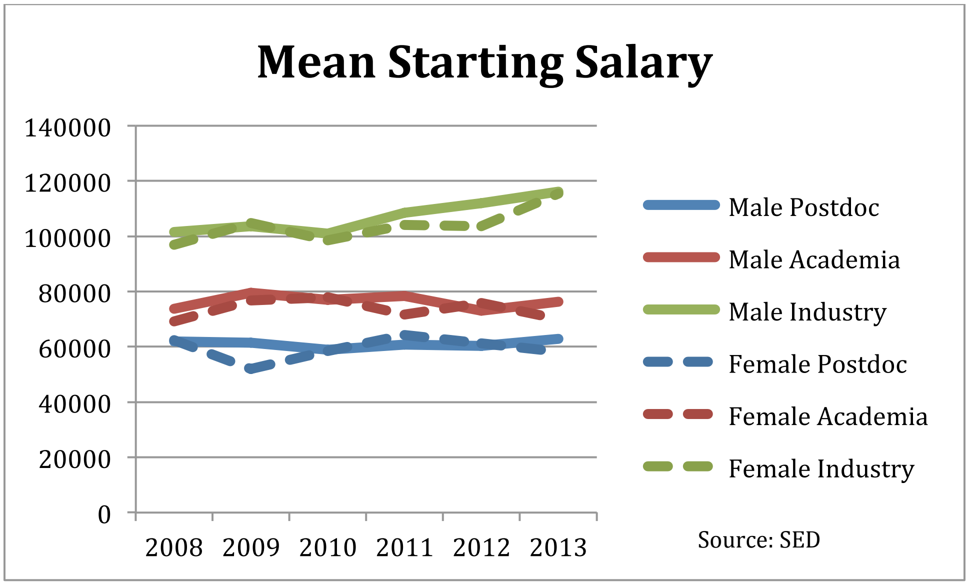


Figure 67. Mean Starting Salary of New PhDs.

### *Work Activities*

The SED asks respondents about the primary work activity of their anticipated employment. Someone taking a faculty position, for example, might expect their primary activity to be research or to be teaching, depending on the type of position. Fig. 68 shows, of those who expect the activity to be their primary work activity, the percent that are female. There is a gradual upward trend in the percent of women among those expecting R&D activities; teaching trends upward until a sharp downturn after 2011. The increasing trend is significant at .01 for both activities. In all years, a higher percent are women among those planning to teach than among those planning to do R&D.

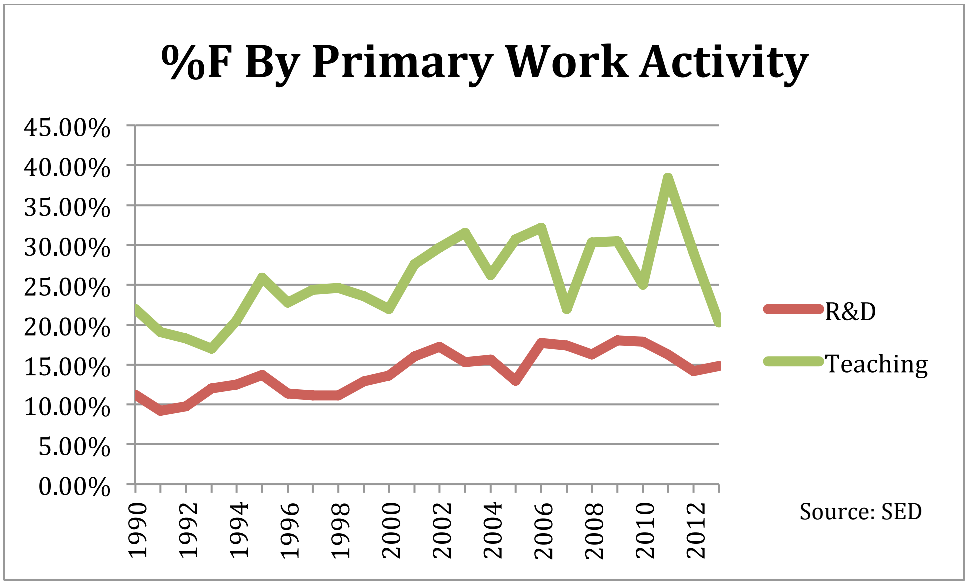


Figure 68. %F By Primary Work Activity.

### *Expected Postgraduation Location*

SED respondents supply their expected work location, which can be coded to inside or outside the US. To be comparable with most of our other trend charts, we would show the percent of those choosing to work outside the U.S. who are female in each year. However, because it seemed likely that a higher percentage of temporary residents would accept positions outside the US, the analysis was conducted separately by gender and by residency (foreign or domestic, with domestic including citizens and permanent residents). Fig. 69 shows the trends for male temporary residents, female temporary residents, and male and female domestic PhD recipients. Because small numbers of female majority students and minority students of both genders take positions outside the U.S., further breakdowns of the domestic trend lines are not shown; the average percent of these groups taking positions abroad between 1990-2013 are: Male majority, 4.3%; male minority, 2.2%; female majority, 3.7%; female minority, 2.2%. For the most recent year (2013), 10.7% of all SED respondents expected to work outside the US, which is greater than the 8.2% taking employment outside North America that was reported by the Taulbee Survey for 2013 graduates. The difference may be due to the inclusion in the Taulbee data of Canadian graduates, the distinction between non-North-American employment in Taulbee and non-US employment in SED, and the more than 20% of graduates for whom Taulbee has no employment data. However, the 2013 Taulbee data does show the same pattern by gender and residency as the SED: Male temporary residents are most likely to accept employment abroad (12%), followed by female temporary residents (8%), male domestic students (5%) and female domestic students (4%).

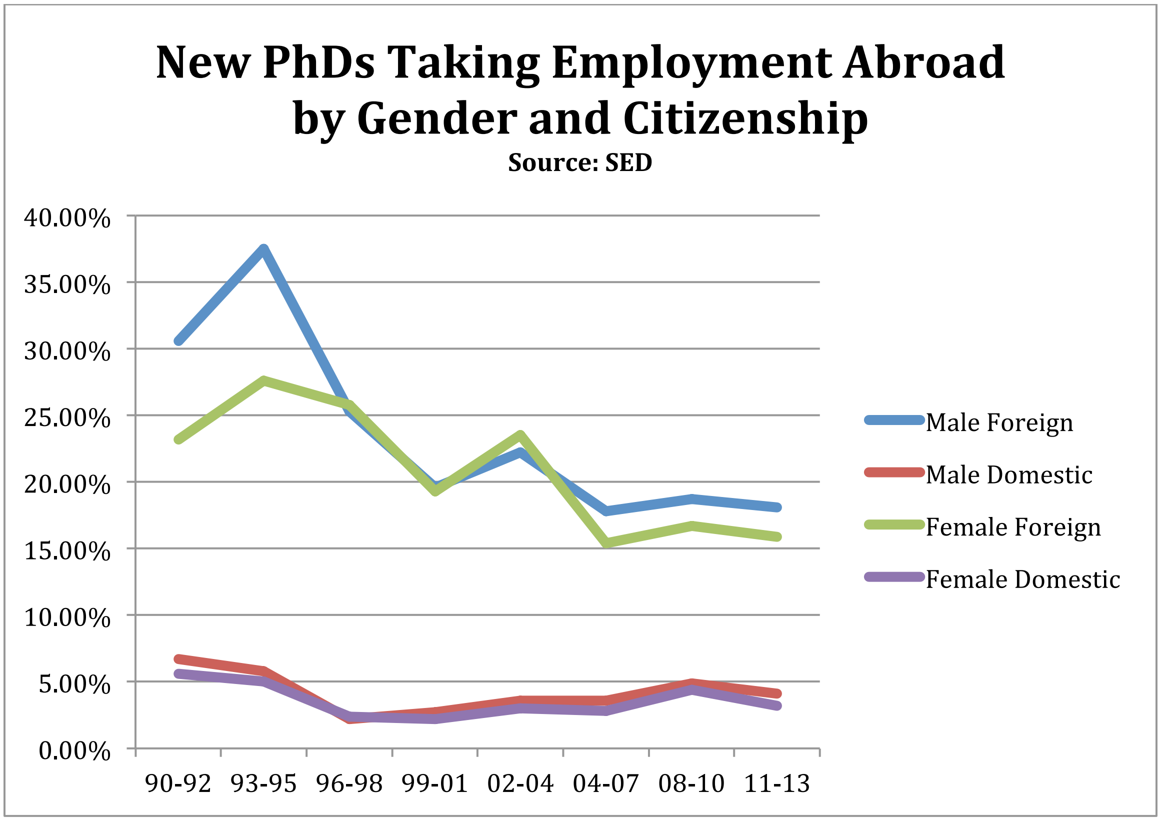


Figure 69. New PhDs Taking Employment Abroad by Gender and Citizenship.

## Other Career Stages

### *Tenure-track Faculty Progression (hypothesis: positive trend)*

The Taulbee Survey provides a source of data about faculty demographics at institutions that grant the doctoral degree in computer science, computer engineering, or information. The reported data is aggregated among the different types of computing departments. Figure 70 shows the trend by faculty rank since 1994.

For all professorial ranks (full professor, associate professor, and assistant professor), there is a significant positive trend in the percentage of women on the faculty at the institutions reporting to the Taulbee Survey (alpha = .01 for full and associate professors, alpha = .02 for assistant professors). This conforms to our hypothesis. Furthermore, for each of the twenty years, the percentage of women on the faculty has been highest at the assistant professor level and lowest at the full professor level.

The new ACM NDC Survey suggests that the percentage of women is highest at the assistant professor level and lowest at the full professor level in non-doctoral-granting computing departments as well. Though there is only one year of an appreciable amount of data from this survey (for the 2013-14 academic year), the reported percentages of women were 29.3 at the assistant professor level, 21.9 at the associate professor level, and 19.5 at the full professor level. Each of these percentages is higher than its Taulbee Survey counterpart for this year of 26.3, 19.8 and 13.5, respectively.

The trends indicate that women are progressing in rank. The graphs also demonstrate that, despite these progressions, it takes many years to effect a large difference in percentages. The current percentages of women at the full and associate professor levels are the same as the percentages in 2007 at the respective associate and assistant professor levels.

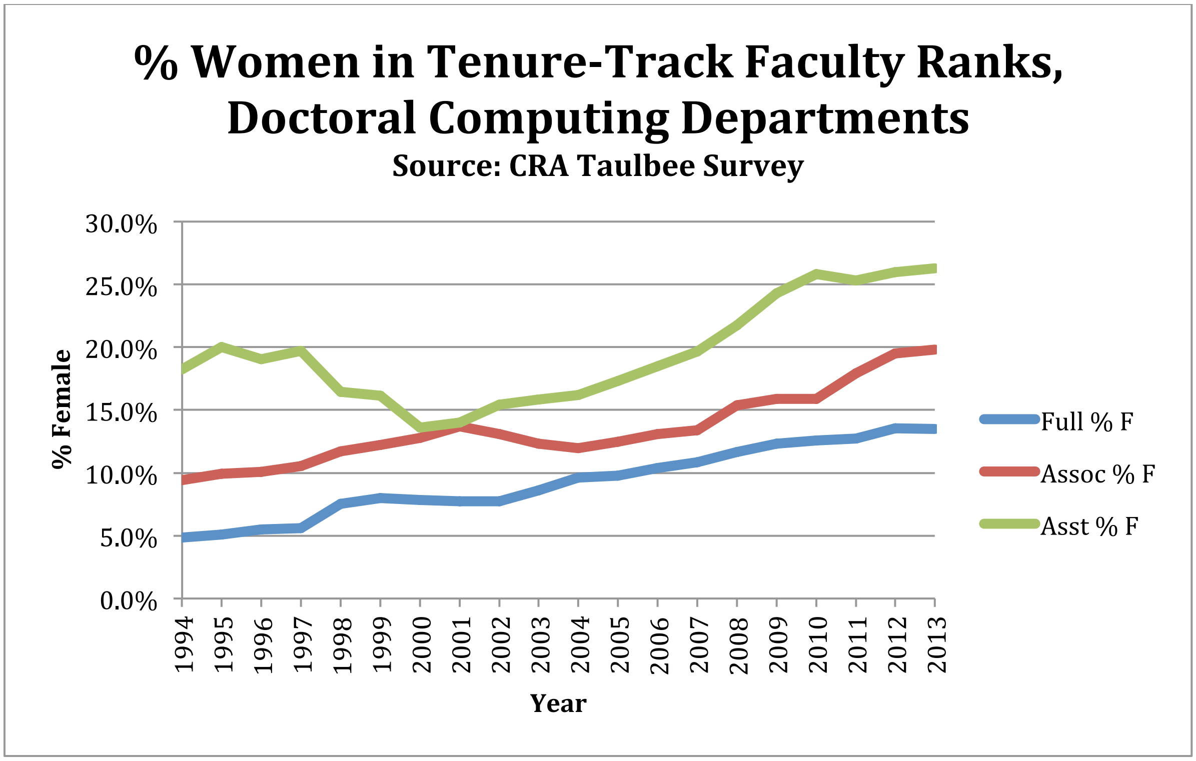


Figure 70. %F in Tenure-Track Faculty Ranks, Doctoral Computing Departments.

### *Professional Society Fellows (hypothesis: positive trend)*

A final aspect of career progression in which we were interested is the trend of recognition of women as fellows of professional societies. The two major societies in computing are the ACM and IEEE Computer Society. ACM fellows are selected annually, and IEEE Computer Society fellows are part of the group of IEEE fellows selected annually. Though information about the society fellows is not available from the data sources used elsewhere in this report, it is available from the society websites. We examined the websites of ACM and IEEE for information about those persons selected as fellows since 1994 (the first year of ACM's fellows program). Figure 71 shows, for each year, the fraction of new ACM fellows who were women, and the fraction, of those new IEEE fellows from the Computer Society, who were women.

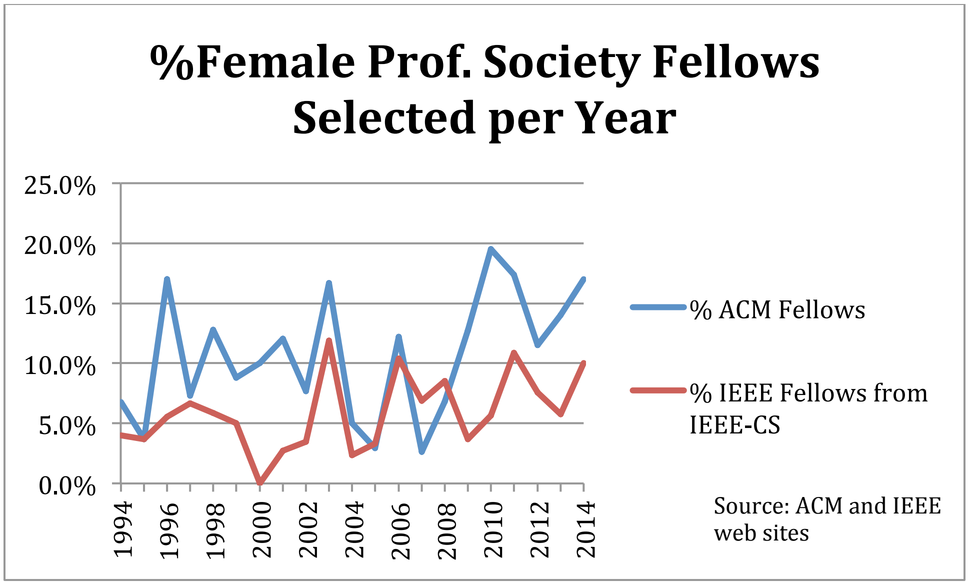


Figure 71. %F Professional Society Fellows Selected per Year.

The graphs show that the year-to-year differences vary greatly. The ACM percentages have been greater than those from IEEE-CS in most years. However, both sets of percentages are very low. Because the total number of fellows selected in a given year is less than 50 in each society, we did not analyze the data for significance of the trend.

Figure 72 shows the professional society Fellows data cumulatively. The cumulative data comprises a sufficiently large number of fellows each year (except the first) for trend analysis. The long-term trend in each society clearly is positive, and is significant at alpha = .01.

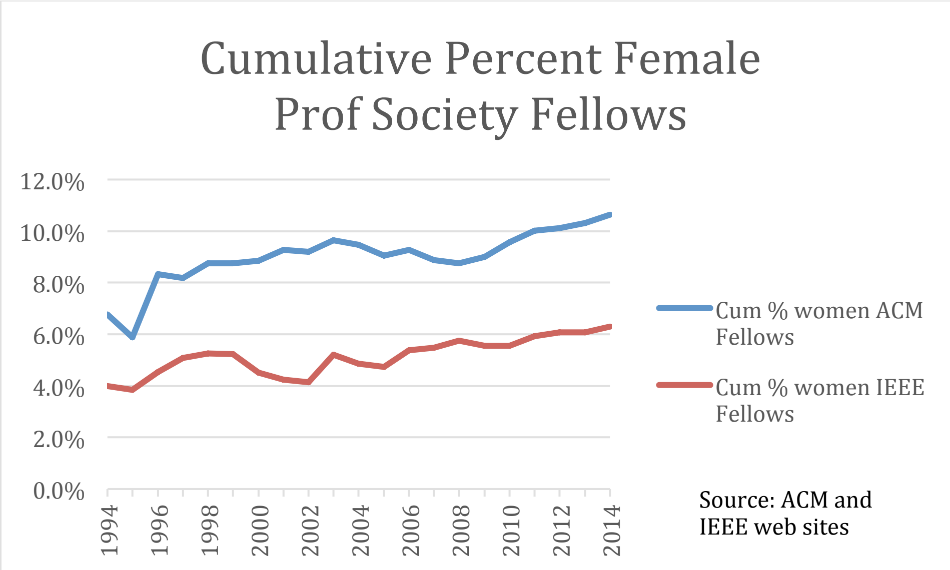


Figure 72. Cumulative Percent Female Professional Society Fellows.

## Conclusions

We looked "under the hood" at the details of women's representation in computing during the past two-plus decades. We analyzed in much greater depth than have previous studies the postsecondary degree data published in IPEDS and the CRA Taulbee Survey. We also analyzed elements of the doctoral education process and data about postgraduation and career advancement from Taulbee, SED and computing professional society fellows. To our knowledge, this is the first study of its kind in terms of its scope and level of detail.

One important contribution of our work is the breakdown of data about the computing field into various disciplines, and the examination of differences across these disciplines. We believe that our classification of CIP codes into the eight disciplines more accurately characterizes the state of, and trends in, postsecondary computing than other categorization approaches. Overall trends and levels of participation by women at the bachelor's, master's and doctoral levels showed differences depending on which discipline was being examined, and in particular showed that some of the newer disciplines and the more interdisciplinary areas of computing frequently are different than the more traditionally-studied area of computer science.

Differences across disciplines also were observed based on institutional characteristics such as public, private for-profit, and private not-for-profit, and based on whether the institution was of a research or non-research Carnegie class. When comparing the fraction of bachelor's degree recipients who are women between private for-profit and private not-for-profit institutions, computer science was the only computing area favoring for-profits, while at the master's level the information technology area was the only one where private not-for-profits had greater representation than publics. No differences of note were observed between non-research institutions that had a significant graduate component and those that did not.

Individual characteristics were important distinguishers between levels of participation by women across most disciplines at all degree levels. Majorities tended to have the least representation by women as compared with either minorities or non-residents. In most disciplines, the trends in participation over time by majorities and minorities were negative (i.e., decreasing) at both the bachelor's and master's levels. The interdisciplinary area was a notable exception to most of those trends. Within the majority area, the trends of participation at both the bachelor's and master's level by Asian women generally were more favorable than those for White women. Within the minority area, the trends among Blacks and Hispanics at the bachelor's level were similar except in the interdisciplinary area. Non-resident trends were most likely to be negative at the bachelor's level, non-significant at the master's level, and increasing at the doctoral level.

The SED data confirmed the increasing trend in the percentage of doctoral degrees by non-residents. Increases also were present in the fraction of women among doctoral graduates whose baccalaureate institution was outside the United States, in particular, from India, the Middle East, South Korea and China.

Women are more likely than men to fund their doctoral studies through fellowships and using their own funding, while men are more likely than women to have RA support for their doctoral studies. Female majorities and minorities (but not non-residents) also tend to take longer than men to complete their doctoral studies, due to the fact that they take more time off during their doctoral studies and, in the case of female minorities, take longer to complete required coursework.

It is of interest to assess how the representation of women changes at key transition points in one's career development. Our IPEDS analysis showed that the representation of women at the master's level is higher than that at the bachelor's level in every discipline, and that the representation at the doctoral level tends to be lower than that at the master's level. The Taulbee data suggests a slight dropoff in the fraction of women among doctoral graduates as compared with the fraction of women among doctoral enrollees, but the current enrollment percentages for women from Taulbee are about the same as those in IPEDS for doctoral graduates.

After doctoral graduation, the fraction of women among those taking postdoctoral positions exhibits little change over time, while there has been an increase in the fraction of women among those taking academic and industry positions. Since there has been an increase in the fraction of new doctoral graduates who are women, this suggests that both academia and industry are benefiting from this increase. A higher percentage of those planning to teach after graduation are women as compared with the percentage of women among those planning to go into research and development. In fact, in academia the percentage of women among new faculty hires at doctoral institutions has exceeded the percentage of women among doctoral graduates. However, the percentage of women among doctoral graduates going to industry is less than the percentage of women among new graduates. This influences overall starting salaries of female doctoral graduates as compared with males; over the last few years, women's salaries were at 93.5% of men's among all doctoral graduates. Among longer-term trends after graduation, we observed increases in the percentage over time of women among faculty at more senior ranks, and in the cumulative percentage of society fellows who are women.

Cognizance of the differences ascertained in our study should be important to those who rely on previously published data to suggest and analyze approaches that will help increase the participation of women in computing. Such increased participation is needed in every dimension we studied, and there are many efforts underway to improve the situation. We hope that our data analysis will better able us to assess the impact of these and future efforts.

## Publications Resulting From This Project

The key results from our IPEDS work were presented at the RESPECT 2015 conference (Zweben & Bizot, 2015). This paper was one of four that received the highest category of ratings from reviewers. We were invited to, and did, submit an expanded version of this paper to the IEEE Computing in Science and Engineering Journal. As of this report, the paper was under review.

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