# Research Productivity of Science and Engineering Faculty at US Universities: The Contribution of Foreign Vs. US-Born Status

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***Abstract:*** *US postsecondary institutions employ a growing number of foreign-born faculty members, yet there is inadequate literature examining faculty who come to US doctoral universities and how outputs from foreign-born faculty compare to US-born peers. Using data from the 2004 National Study of Postsecondary Faculty (NSOPF:04), this study examines research productivity of faculty members in the sciences and engineering by foreign- vs. US-born status and select individual and institutional characteristics. Findings can contribute to policy-level discussions on future entry of foreign-born scholars to US institutions, continued or increased knowledge production, and optimal student learning. Implications for faculty integration into the campus community, graduate student and postdoctoral research training, and international travel policies are discussed.*

Knowledge production via faculty member research is important to economic development and a key part of the mission for doctorate-granting universities. The contemporary emphases on efficiency and productivity have heightened the professoriate role of research and knowledge production (Bean, 1998; Tien, 2008). The number of foreign-born full-time faculty members in the US nearly tripled from 28,200 in 1969 to 74,200 in 1998 (Schuster & Finkelstein, 2006), and of the 21.6 million scientists and engineers in the US in 2003, 16% were immigrants (NSF Info Brief, 2007). Because today's university scientists are increasingly a mix of US- and foreign-born scholars, considerable interest in faculty members who conduct research in institutions outside their native land is growing. The ways in

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which faculty members use their work time affect instruction, student-faculty interactions, and collective research output for the institution. Limited studies have examined the research productivity of foreign-born scholars in US institutions. Studies by Corley and Sabharawal (2007), Lee (2004), Levin and Stephan (1999), Stephan and Levin (2007), and Mamiseishvili and Rosser (2010) and all found that, on average, foreign-born faculty are more productive than US-born faculty. However, none have specifically examined research production of faculty in the sciences and engineering (S&E), and very few studies have examined productivity through the latest national survey of postsecondary faculty, the *National Study of Postsecondary Faculty*(NSOPF:04). The current study is also unique in that no other studies have examined research production of S&E faculty members in NSOPF:04 employing the application of hierarchical generalized linear modeling (HGLM). This application of multilevel modeling is important because it can address the non-normal distribution of productivity count data, allowing us to examine the contribution of important individual characteristics nested within characteristics of the institution. Although foreign- vs. US-born is a focus of this study, an examination of productivity without other individual and institutional characteristics would prove incomplete, thus this study incorporates a select set of individual and institutional factors to ensure a more comprehensive understanding of the questions under study.

**Increases in International Scientists in US Universities**

Individuals born outside the US comprise a substantial proportion of scientists and engineers in the US labor force. From 2001 through 2010, over 400,000 professionals with advanced degrees or aliens of exceptional ability obtained legal permanent residence status in the US (*Yearbook of Immigration Statistics, 2010*). Many of these individuals are employed in postsecondary education; Lin, Pearce, and Wang (2009) report that foreign-born individuals account for approximately 22% of today's postsecondary faculty workforce. The increase in foreign-born faculty on US universities is due, in part, to global higher education efforts such as the emergence of an international labor market, ease of faculty mobility across international boundaries, and large numbers of students who study abroad (Mamiseishvili & Rosser, 2010). As well, efforts to internationalize higher education can be seen in many teaching and research activities of universities. Altbach (2005) believes that the demands of a globally-knowledgeable society have placed pressure of higher education to focus on select activities, approaches and

outcomes. Research production in certain disciplines such as information technology and life sciences is a "high priority" for many universities (p. 26).

As countries attract the 'best and brightest' scholars for university research and development, faculty productivity may benefit from the presence of creative, inventive, and entrepreneurial individuals. Immigrant scholars may contribute in positive ways (i.e., Hunt & Gauthier-Goiselle, 2008; Stephan & Levin, 2003), or they may reduce the chances for US-native success (for example, Altbach 2005, Altbach, Reisberg, & Rumley, 2009; Hser 2005; Hunt, 2009; Sheppard 2004; Stromquist, 2007). Hunt asserts that the increase in immigrant workers could positively increase the size of the population and subsequent economic benefits that occur, or, in contrast, immigrants may be more creative or entrepreneurial and outperform native workers. The latter has been noted, for example: Peri (2007) reported that immigrants are over-represented in US-based Nobel Prize winners, Wadhwa, Jasso, Rissing, Gereffi, and Freeman (2007) found that 24% of international patent applications from the US were from non-US citizens, and Stephan and Levin (2001) found a proportionately higher number of immigrants were members of the National Academy of Sciences and the National Academy of Engineering. On the other side of the debate, Matloff (1988) reports that the majority of technical advances in computer science and engineering have been made by US natives. Because knowledge production is important to a region or country's economic and educational strength, the issue of individual contribution remains important for additional study.

## Purpose of This Study

Due to an increase in the number of international S&E faculty at US institutions, it is important to learn more about foreign-born faculty and how they compare to US-native faculty members. There are growing numbers of international agreements between institutions for faculty exchanges, scholarship and fellowship programs, collaborative research, and professional/scholarly meetings that keep academics engaged in international work and study. Such collaborations have important implications related to workload, institutional resources, and quality of life that call for greater study. Therefore, the purpose of this study is to provide information on foreign-born S&E faculty at US doctoral institutions and how they compare to US-born S&E faculty members. While some findings

are available (i.e., Corley & Sabharawal, 2007; Lee, 2004; Mamiseishvili & Rosser, 2010), gaining a better understanding of research productivity in light of individual and institutional characteristics will provide insight into the success of faculty members, ways to increase knowledge production, and will have relevance to possible changes in international travel and study. While concerns are noted for the possibility of native worker displacement (Hunt, 2009) or depressed wages for native Ph.D. holders (Borjas, 2006) it is likely that faculty, students, and institutions as a whole benefit by incorporating talent with global expertise to a campus that fuels innovation, and creativity, and enhanced student learning and knowledge production. A fundamental goal for US postsecondary education is enhancing myriad opportunities for learning from diverse peers that come from all parts of the world, and international faculty can assist in achieving this goal.

## Literature Review

Due to the increase in foreign-born scholars, some recent studies are beginning to explore research productivity by immigrant or country of birth status. Examining different sources of data, Webber (2012), Betsey (2007), and Corley and Sabharwal (2007) found that foreign-born scientists were more productive than their US peers. Relatedly, Mamiseishvili and Rosser (2010) found international faculty members significantly more productive in research but less productive in teaching and service. Because postsecondary education earned in a foreign country results in lower wages in the US, Hunt (2009) found that immigrants who entered the US on student or temporary work visas had a large advantage over natives for wages, publications, presentations, patents, and commercialized licenses for patenting. Several studies by Stephan and Levin found similar results in select science and engineering fields (e.g., Levin & Stephan, 1991; 1999; Stephan & Levin, 2007). Using patents, citations in select prestigious journals, and election to NAS or NAE as the criteria for exceptional productivity, these authors found that, overall, greater research contributions came from faculty who were foreign born.

Although immigrant or foreign-born status is important, other variables may also contribute to faculty productivity, and inclusion of these variables allow a more complete examination of this issue. A number of studies examined differences in faculty work by individual characteristics such as gender, race, marital status, and rank. Schuster and Finkelstein (2006) and Creamer (1998), report that senior faculty members publish more than their junior

peers, and Fairweather (2002) found full professors to be the most highly productive researchers. This finding is logical when one considers the time needed to develop a strong research agenda, obtain extramural funding, and establish a lab and/or complement of graduate research assistants. Time devoted to teaching may also affect research productivity. While there is some evidence that teaching and research can be complementary (Feldman, 1987), other studies examining the nexus between teaching and research (including a meta-analysis by Marsh and Hattie, 2002 and study by Link, Swann, and Bozeman, 2008) found that teaching and research are not complementary but instead compete for one's time. The mixed findings in this area prompt additional study of faculty roles in teaching and research.

In addition to age, rank, tenure status, and teaching, the effect of gender on research productivity continues to be monitored. Fairweather (2002) found that women were less likely to be highly productive researchers, in part because they teach more, and were more likely to use active or collaborative teaching methods. Cole and Zuckerman (1987) reported that female faculty publication rates are approximately 2/3 the rate for male peers, and Long, McGinnis, and Allison (1993) found that women in the sciences were less likely to be promoted because they produced fewer published articles. While the gender gap narrows when institutional type, level of doctoral training, discipline, and level of career are controlled (Ward & Grant, 1996), Schuster and Finkelstein (2006) reported that the proportion of prolific publishers among men was twice as great as among women in 1998 compared to a decade earlier.

Related to gender, some scholars have examined the effect of marriage and children on faculty productivity. Perna (2005) reported a negative effect for family ties for women, and Creamer (1998) reported that the presence of children had a significant negative effect on female faculty's publication rates. Bellas and Toutkoushian's (1999) analysis of 1993 NSOPF found that on average, married and male faculty have higher levels of research output, and Mason and Goulden (2004) found that male faculty with young children have a significantly higher likelihood of earning tenure than female peers. Controlling for factors such as discipline, age, and type of institution, they found that women spend significantly more time in teaching and men spend more time in research.

Along with demographics characteristics, Bland and colleagues (Bland & Ruffin, 1992; Bland, Center, Finstad, Risbey, & Staples, 2006), Brocato and

Mavis (2005) , Creamer and McGuire (1998) and Creswell (1985) discuss the notion of cumulative advantage. Scholars who earned graduate degree(s) from prestigious institutions, received strong mentoring, and who earned recognition from accomplishments early in their career are likely to have higher total scholarly works. Somewhat at odds, however, are the consistent findings by Cole (1979), Levin and Stephan (1989) and others summarized in Lawrence and Blackburn (1988) who find that productivity declines as age increases. Levin and Stephan point out that differences exist by discipline, but see declines in most fields by about age 50. Posited reasons for the decline include the need to choose among multiple role demands, the realization that one may not be a star scholar once hoped at an earlier age, or a greater affinity for searching for new knowledge regardless of the financial or reputation reward. The interesting relationship between cumulative advantage and age related to productivity prompts additional study.

As US postsecondary education continues to seek a diversified faculty population and globalized policies with research rewards, greater understanding of foreign-born faculty is paramount. Thus, using data from the 2004 NSOPF at US postsecondary institutions, this study examines differences in faculty members' research productivity by citizenship/immigrant status and discipline. Specifically, the following three questions are examined:

1. Who are the foreign-born S&E faculty members employed at US doctoral universities (by demographic characteristics such as gender, tenure status, and rank)?
2. How do production counts, salary, and satisfaction differ for foreign-born vs. US-born S&E faculty?
3. What individual and institutional factors contribute to research productivity for S&E faculty, specifically do foreign-born vs. US-born status, gender, rank, marital status, dependent children, percentage of time apportioned to research and instruction, career productivity, satisfaction, funds apportioned to research, faculty to student ratio, and institution type affect research productivity, defined as scholarly writings generated over a two-year period?

## Conceptual Framework Guiding This Study

An understanding of the factors contributing to faculty productivity can be enhanced by examining individual motivations for education, skill development, and finance. Principles of human capital theory assist in

understanding faculty productivity because attributes such as knowledge, skills, values, education, and training affect productivity (Becker, 1993). Individuals are willing to spend a great deal of time and effort early in their career to broaden these attributes, accepting lower salaries, with the hope that there will be a larger return on their investment as their career matures. Scholars such as Paul and Rubin (1984) use the human capital framework to examine faculty productivity in numerous ways including issues related to tenure, salary, and the relationship between teaching and research. Specifically, applying the human capital paradigm to the publication question offers insight into why publications are rewarded and purports that "research is a necessary stimulus to quality instruction" (p. 145). As well, the generation of scholarly products including patents is an important component of a faculty member's human capital. Some scholars frame the faculty salary disparity as a function of market segmentation, suggesting that more women work at institutions with lower prestige and spend more time on work roles (such as teaching and committee work) that are not rewarded (Smart, 1991). Related to foreign-born faculty, it is of interest to determine if dimensions of human capital lead to similar or different levels of productivity. Some are concerned that foreign-born faculty may provide cheap labor (Hunt, 2009; Saxenian, 1999), while others believe foreign-born faculty can spur scientific innovation and increase US competition (Stephan & Levin, 2001).

Explanation for the higher research productivity of foreign-born versus US-born faculty also relate to motivation and/or cultural attitudes. The theory of achievement motivation is relevant for understanding attitudes and behaviors about work (Atkinson & Feather, 1966). Related to motivation, high research productivity may be due to embedded cultural and/or family standards for strong work ethic that affect some immigrant groups more than others (Harrell, 1985; Taylor & Stern, 1997). Foreign-born faculty may also be motivated to work in the US for access to better research facilities, a larger relevant information base, economic opportunities, and better living conditions (NSF Press Release 07-073; Shkolnikov, 1994) or because of one's legal status and temporary nature of the H1 visa (Espenshade & Rodriguez ,1997). Motivation for foreign-born faculty working in the US may also be due to need to gather income and/or skills so they can return home for a desired job in their native land (Saxenian, 1999). These factors, subtle or strong, may contribute to time and energy put toward work and a direct outcome for research production.

## Data and Method

Data for this study came from the 2004 *National Survey of Postsecondary Faculty* (NSOPF:04). The 2004 administration of NSOPF is the most recent national survey of postsecondary faculty coordinated by the federal government and was administered to approximately 30,000 faculty in nearly 1,000 US institutions. With an overall response rate of 85%, responses were received from over 26,000 faculty members. Because this study focused on research productivity, responses from faculty members in doctoral-granting institutions were selected. The sample for this study included approximately 1,800 faculty members in over 200 doctorate-granting institutions and excluded non-tenure track, part-time faculty, and full-time faculty who did not have teaching or research as their primary duty.

### Variables Used in This Study

The literature on increases in a diverse professoriate and faculty research productivity discussed above guided the selection of variables included in this study. The dependent variable, recent scholarly written products, is the total number of academic written products completed in the past two years, including refereed and non-refereed journal articles, book chapters, reviews, books, and textbooks. Scholarly presentations, exhibits, performances and patents were not included due to their wide range of distribution (very small number of patents and performances, and presentations that can have a very large range in content and purpose).

A main focus of this study is the difference in productivity by US-vs. foreign-born status, but previous work by many scholars including Blackburn and Lawrence (1995), Creswell (1986), and Bland et al. (2006) urge a broader examination to accurately understand faculty productivity (Bland & Ruffin, 1992; Bland et al., 2006). Based on these scholarly works, the current analysis includes a select set of demographic and institutional characteristics that have been shown to affect research productivity, shown in Table 1. Individual demographic characteristics included gender, marital status, having dependent-aged children, rank, and age. Also included were important individual work roles including the percent of time spent on research, percent of time on instruction, satisfaction with employment, and one's written scholarly products produced over one's career. Based on the literature, characteristics of the institution were also examined and included the ratio of research expenditures divided by total expenditures, student-

faculty ratio, level (intensive vs. extensive), and type of institution (private vs. public).

Table 1
*Descriptive Statistics for Dependent and Independent Variables*

| | N* | Min | Max | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Total recent written works | 1820 | 0 | 66 | 9.55 | 8.864 |
| Born in United States (1=yes, 0=no) | 1820 | 0 | 1 | .66 | .473 |
| Married (1=yes, 0=no) | 1820 | 0 | 1 | .8160 | .38756 |
| Children (1=yes, 0=no) | 1820 | 0 | 1 | .5887 | .49221 |
| Female (1=yes, 0=no) | 1820 | 0 | 1 | .2120 | .40882 |
| Rank Full Professor (1=full, 0=other) | 1820 | 0 | 1 | .4349 | .49588 |
| Percent time on Instruction | 1820 | .00 | 100.00 | 46.52 | 22.495 |
| Percent time on Research | 1820 | .00 | 100.00 | 40.56 | 22.423 |
| Age at time of survey | 1820 | 27.00 | 78.00 | 49.47 | 10.164 |
| Satisfaction Index employment items | 1820 | 0 | 12.00 | 7.92 | 2.633 |
| Recent articles, refereed journals | 1820 | 0 | 30 | 6.06 | 5.959 |
| Recent articles, non-refereed journals | 1820 | 0 | 30 | 1.84 | 3.710 |
| Recent book reviews, chapters, creative works | 1820 | 0 | 20 | 1.01 | 1.960 |
| Recent books, textbooks, reports | 1820 | 0 | 20 | .64 | 1.667 |
| Recent presentations | 1820 | 0 | 50 | 7.07 | 7.565 |
| Recent exhibitions, performances | 1820 | 0 | 65 | .20 | 2.483 |
| Recent patents, computer software | 1820 | 0 | 10 | .27 | .844 |
| Ratio research to total expenditures | 1800 | .00 | .47 | .2172 | .09328 |
| Ratio of FTE enrollment/FTE faculty | 1820 | 2.00 | 25.00 | 12.39 | 4.802 |
| Type (Private=1, 0=public) | 1820 | 0 | 1 | .2317 | .42206 |
| Level (1=doctoral extensive, 0=doctoral intensive) | 1820 | 0 | 1 | .8056 | .39585 |

*All Ns are weighted and rounded.

Initial analyses examined faculty respondents by country of birth (US-born yes/no) and citizenship status. Because just over half of the foreign-born faculty said they were US citizens, there is the potential for inaccuracy that may result from the citizenship variable, thus all subsequent analyses were completed with the US-born variable.

**Multilevel Modeling Strategy**

Analyses for this study included initial descriptive analyses followed by a hierarchical generalized linear analysis to examine individual and institutional characteristics related to total recent written products. Some scholars believe the use of traditional OLS regression is inappropriate when examining data at multiple levels (Hahs-Vaughn, 2006; Thomas & Heck, 2001) because it may result in inaccurate parameter estimates. The use of hierarchical modeling overcomes this concern by simultaneously estimating equations for both individual and institutional effects. In addition, multilevel analyses take clustered data structures into account when producing estimates for within and between-group variances and do not require testing for design effects (Thomas & Heck, 2001).

Exploratory analyses found that many faculty members had zero scholarly products, showing a strong skew toward zero (can be seen in Table 1), and this is problematic for standard multilevel modeling. To accommodate for the non-normal distribution, a two-level hierarchical generalized linear model (HGLM), Poisson distribution with overdispersion was used, HLM version 6.06. For the dependent variable used in this study, the Poisson distribution enables a more normal distribution with the assumption that variance and expected number of events (mean) are equal. Analyses for this study used the sampling weight for faculty included in the NCES restricted dataset, plus one additional weight transformation. To correct for possible oversampling, the raw faculty weight was recoded into a relative weight by dividing the raw weight by its mean.

Many scholars who use multilevel models begin with a null model followed by one or more models that incorporate additional variables (Raudenbush & Bryk, 2002). The null model includes no predictor variables, but estimates the variance that exists within and between institutions. The dependent variable for this analysis was total recent scholarly written products (refereed and non-refereed journal articles, book reviews, book chapters,

books, and textbooks. Using the Poisson option with overdispersion, the null model with fixed slopes is shown as:

Level 1 Model
E(Number scholarly products|β)=λ
where Log(λ)=$\beta_0$
Level 2 Model
$\beta_{0j}=\gamma_{00+}\ u_{0j}$ ~N(0, $\tau_{00}$)

where $\gamma_{00}$ is the log-odds of research products across institutions and $\tau_{00}$ is the variance between institutions and institution-average log-odds of research products. Following examination of the null model and guided by literature review and preliminary analyses, subsequent models can add additional predictor variables to determine the increase in total variance accounted for from the predictor variables.
Thus, the second model included additional individual and institutional characteristics guided by previous literature on research productivity. With a random intercept and fixed slopes, the full model is expressed as:

Level 1 Model
E(Recent Scholarly Written Products|β)=λ
Log(λ)=η
$\eta=\beta_0+\beta_1$(Born in US)+$\beta_2$(Female)+$\beta_3$(Married)+$\beta_4$(Dependent Children)+ $\beta_5$(Rank –full professor)+ $\beta_6$(Age)+ $\beta_7$(Satisfaction with Employment)+ $\beta_8$(% Time on Research)+ $\beta_9$(% Time on Instruction)+ $\beta_{10}$(Career Written Products-Recent Written Products)+ r
Level 2 Model
$\beta_0=\gamma_{00}+\gamma_{01}$(Ratio Research Expenditures/Total)+ $\gamma_{02}$(Mean FTE Student-Faculty Ratio) + $\gamma_{02}$(Private)+ $\gamma_{02}$(Doctoral Intensive)+ $u_1$
$\beta_1=\gamma_{10}$
$\beta_2=\gamma_{20}$
...
$\beta_{10}=\gamma_{110}$

Continuous variables including percent of time apportioned to teaching and research, age, publications (total career written products minus total recent written products), and ratio of research to total expenditures. Mean faculty to student ratio were grand mean centered and dichotomous and categorical variables were uncentered. No outliers were present and missing data was removed in each analysis as needed.

# Results

## General Findings on Demographics, Research Productivity, and Satisfaction

As shown in Table 2, just over 60% of the science and engineering (S&E) faculty in US doctoral institutions were born in the US. For both foreign and US-born faculty, the large majority of science and engineering faculty were male, but an even smaller proportion of women were foreign born. Approximately a third more US-born S&E faculty were full professors, and approximately a third more foreign-born faculty respondents were in the junior rank of assistant professor. Along with lower rank, more foreign-born faculty are on track but not yet tenured. Relatively the same percentage of US and non-US born faculty were single or married, but more US-born faculty were separated, divorced or widowed. Related to discipline or field, proportionately more US-born faculty were in the biologic and biomedical sciences, but more foreign-born faculty resided in engineering and mathematics and statistics.

Shown in Table 3, US and foreign-born faculty had similar numbers of non-refereed articles, book reviews, and book chapters published in the two-year period, but the number of other recent scholarly products was significantly higher for foreign-born faculty. In particular, science and engineering foreign-born faculty produced significantly more refereed journal articles, scholarly presentations, and patents and software. It is interesting to note that the total number of scholarly products over one's career did not reach the level for significant difference across the two groups, but more foreign-born faculty were younger (mean age for US-born faculty was 50.79, compared to 47.36 for foreign-born peers). Regarding salary, no significant difference was found in mean base income earned from one's institution, but US-born faculty reported higher consulting/freelance and total annual income.

Table 2
*Select Demographic Characteristics by Birth Country, Born in US*

| | | Born in US | | Foreign-Born | |
|---|---|---|---|---|---|
| Total | | N* 1120 | % | N* 700 | % |
| Gender | Male | 900 | 75.5 | 600 | 85.4 |
| | Female | 230 | 20.1 | 100 | 14.6 |
| Rank | Assistant professor | 240 | 21.6 | 210 | 30.2 |
| | Associate professor | 350 | 30.7 | 210 | 30.5 |
| | Full professor | 540 | 47.7 | 280 | 39.3 |
| Terminal Degree Date | 1979 or earlier | 400 | 35.3 | 170 | 23.7 |
| | 1980-1990 | 380 | 34.1 | 210 | 30.4 |
| | 1991 or later | 340 | 30.6 | 320 | 45.9 |
| Tenure Status | Tenured | 840 | 75.0 | 450 | 65.6 |
| | On Tenure Track | 280 | 25.0 | 240 | 34.4 |
| Marital Status | Single, never married | 90 | 7.9 | 60 | 8.6 |
| | Married | 920 | 82.3 | 590 | 84.0 |
| | Living w/significant other | 30 | 2.9 | 20 | 3.1 |
| | Separated, divorced, widowed | 80 | 6.8 | 30 | 4.3 |
| Research Field | Agriculture/natural resources | 80 | 7.5 | 20 | 2.6 |
| | Architecture & related | 20 | 2.0 | 20 | 2.4 |
| | Biological & Biomedical Sciences | 320 | 28.1 | 150 | 21.6 |
| | Computer/Information Science | 40 | 3.8 | 70 | 10.0 |
| | Engineering & Engineering Technologies | 180 | 15.7 | 180 | 26.0 |
| | Health Professions | 200 | 17.7 | 70 | 10.1 |
| | Mathematics and Statistics | 90 | 7.9 | 90 | 12.3 |
| | Physical Sciences | 190 | 17.1 | 100 | 14.4 |

*All Ns are weighted and rounded. Due to rounding numbers may not equal total or 100 percent.

Table 3
*Scholarly Products, Satisfaction, and Income for US- vs Foreign-Born Faculty*

| | US-Born Faculty | | | Foreign-Born Faculty | | | |
|---|---|---|---|---|---|---|---|
| | N[a] | Mean | SD | N | Mean | SD | Sig |
| Refereed articles | 1120 | 5.87 | 5.962 | 700 | 7.10 | 6.493 | ** |
| Non-refereed articles | 1120 | 1.79 | 3.589 | 700 | 2.13 | 4.361 | |
| Book rev, book chapters | 1120 | 1.03 | 2.124 | 700 | 1.06 | 1.843 | |
| Books, textbooks | 1120 | 0.60 | 1.716 | 700 | 0.66 | 1.597 | |
| Presentations | 1120 | 6.87 | 7.826 | 700 | 8.03 | 7.978 | ** |
| Patents, software | 1120 | 0.26 | 0.850 | 700 | 0.36 | 1.022 | * |
| Total recent written works | 1120 | 9.28 | 8.704 | 700 | 10.95 | 10.285 | ** |
| Total career products | 1120 | 72.16 | 71.702 | 700 | 74.22 | 76.198 | |
| Authority to make decisions*** | 1120 | 1.22 | 0.506 | 700 | 1.37 | 0.629 | ** |
| Technology activities | 1120 | 1.78 | 0.777 | 700 | 1.81 | 0.787 | |
| Equip/facilities | 1120 | 1.92 | 0.821 | 700 | 1.93 | 0.838 | |
| Institutional support teaching activities | 1120 | 2.16 | 0.872 | 700 | 2.20 | 0.942 | |
| Workload | 1120 | 2.02 | 0.856 | 700 | 2.01 | 0.838 | |
| Salary | 1120 | 2.24 | 0.903 | 700 | 2.41 | 0.976 | ** |
| Benefits | 1120 | 1.90 | 0.807 | 700 | 2.05 | 0.842 | ** |
| Job overall | 1120 | 1.74 | 0.757 | 700 | 1.88 | 0.755 | ** |
| Base salary | 1120 | $86,363 | $35,027 | 700 | $83,759 | $33,258 | |
| Income from consulting, freelance | 1120 | $3,492 | $9,042 | 700 | $2,573 | $6,422 | ** |
| Total income | 1120 | $103,396 | $45,928 | 700 | $99,923 | $42,469 | * |

[a]all Ns are weighted and rounded
*p <.05; ** p<.01
***satisfaction items are scaled 1=very satisfied, 2=someone satisfied, 3=somewhat dissatisfied, 4= very satisfied

Regarding satisfaction, responses indicate general positive satisfaction for both groups; however, there were some significant differences between the two groups. While both groups were similar in level of satisfaction with technology, equipment and facilities, institutional support for teaching, and workload, US-born faculty reported significantly higher satisfaction on four items: satisfaction with authority to make decisions; salary; benefits; and overall satisfaction.

**Factors Contributing to Recent Written Research Productivity**

To further explore factors related to research productivity in science and engineering, hierarchical generalized linear (HGLM) modeling was employed. The unconditional model for total research productivity produced a grand mean for total recent scholarly products of 9.627 (log value=2.264, SE=.0305, $p < .001$), meaning that the average number of written scholarly products for all faculty in doctorate-granting institutions in the two year period was 9.627. Following the null model, I ran two additional HGLM models, shown in Table 4. Because a central focus of this study was productivity by US- vs. foreign-born status, Model One included the variable for US- versus foreign-born status. As shown, foreign-born S&E faculty produced approximately 18% more written scholarly products over the two-year period than US-born peers.

Table 4
*HGLM Results, Variables Contributing to Recent Written Scholarly Works*

| | Model One | | | Model Two | | |
|---|---|---|---|---|---|---|
| | **β Coefficient** | **Exponential β** | **Sig** | **β Coefficient** | **Exponential β** | **Sig** |
| **Intercept** | 2.3767 | 10.7695 | ** | 2.0395 | 7.6868 | ** |
| **Level 1** | | | | | | |
| Born US (1=yes) | -0.1934 | 0.8241 | ** | -0.0769 | 0.9260 | ** |
| Female (1=yes) | | | | -0.0505 | 0.9508 | |
| Married (1=yes) | | | | 0.1571 | 1.1702 | ** |
| Children (1=yes) | | | | 0.0320 | 1.0326 | |
| Rank (1=full prof) | | | | 0.0420 | 1.0429 | |
| Age (time of survey) | | | | -0.0240 | 0.9762 | ** |
| Percent Time on Research | | | | 0.0038 | 1.0038 | ** |
| Percent Time on Instruction | | | | -0.0003 | 0.9997 | * |
| Satisfaction with Employment Index | | | | -0.0092 | 0.9909 | |
| Career Works Less Recent Written Works | | | | 0.0072 | 1.0072 | ** |
| **Level 2** | | | | | | |
| Ratio Research Expenditures to Total Expenditures | | | | 0.4983 | 1.6459 | * |
| Mean FTE to Faculty Ratio | | | | -0.1181 | 0.8886 | * |
| Private/Public (1=private) | | | | -0.1061 | 0.8994 | * |
| Doctoral Level (1=intensive) | | | | -0.0301 | 0.9704 | |
| **Variance Components** | | | | | | |
| Level 1 σ2 | 7.6917 | | | 3.6506 | | |
| Level 2 τoo | 0.0428 | | ** | 0.0634 | | ** |
| Additional Variance over Null | 2.01% | | | 53.49% | | |

*p<.05; **p<.01

Because the variable for US- versus foreign-born status accounted for only two percent of the variance over the null model and the model was not saturated, variables were added. Shown in Model Two of Table 4, foreign-born S&E faculty continued to produce more recent written products than US-born peers, as did married faculty members compared to those unmarried. Model Two accounted for 54% of the variance, and shows that variables other than US- vs. foreign-born status also contributed to recent research productivity. Of note, younger faculty produced about 3% more written products than older faculty. Time spent on research and research completed over one's career (total career works less recent written works) was a significant predictor of recent research production while time spent on instruction was negative. Findings show that time spent on research, instruction, and total career works were all significant, however coefficients for all three were close to zero, so findings may indicate little practical significance.

To examine institutional effects, four other variables were included at level two, shown in Model Two of Table 4. These variables were ratio of expenditures for research to total expenditures; mean ratio of students to faculty (full-time equivalent); public versus private type; and doctoral level (intensive versus extensive). Although institutional level did not have a significant effect on research productivity, HGLM results showed that institutions which apportioned more funds to research, that had a lower student to faculty ratio, and had the public designation employed faculty who were more productive in written research products. Shown in Model Two, faculty in public institutions produced about 10% more written products than peers at private doctoral institutions, and for each standard deviation increase in research expenditures, total recent scholarly works increased by approximately 65 percent.

## Discussion

Knowledge production and the communication of that knowledge is a critical element of the academic enterprise, primarily entrusted to faculty members. Although there is some variation by discipline, research production for many scholars is focused on refereed journal articles and other written documents. The number of refereed articles reported by respondents in these national surveys confirms that it is a primary mode of communication by which most faculty share their knowledge.

Results from the descriptive tables and multilevel analyses herein show some distinct differences between US-born and foreign-born S&E faculty in US doctorate-granting institutions. As a group, the foreign-born faculty members are younger, hold junior rank, and fewer are tenured compared to US-born peers. Despite their more junior level in tenure and rank, foreign-born S&E faculty are producing more scholarly written works than US-born peers. However, while foreign- vs. US-born status is important to consider, analyses shown in Table 4confirm that research productivity is based on a number of individual and institutional characteristics.

Total annual salaries and supplements from consulting/freelance were higher for US-born S&E faculty; this may be related to more US-born faculty earning their terminal degree earlier, having worked in higher education for more years, and holding the full professor rank. Foreign-born faculty may also be more satisfied with somewhat lower salaries if comparing to potential salaries they might earn in their native country. For example, a report by the European Commission Research Directorate (2007) shows that the EU25 average (40.126 EUR) for researchers in the public and private sectors is below the US average of 62.793 EUR.

Along with satisfaction on salary and benefits, US-born faculty reported significantly higher satisfaction than foreign-born peers with their authority to make decisions and job overall. Ultimately, however, the index of satisfaction items did not contribute significantly to the regression model for recent written products (Table 4). Higher rank and tenure status for US-born faculty may contribute to their perception in authority to make decision. It is also possible that native faculty members are somewhat more comfortable with their English language and teamwork, and may have developed a stronger role among their peers for leadership, committee work, or collaboration on research projects which may add to their feeling of overall satisfaction and ability to make decisions. Although foreign-born faculty reported lower satisfaction with salary and authority to make decisions, they reported similar high levels of satisfaction for technology, equipment and facilities, and workload. Satisfaction with technology, equipment, and facilities is consistent with reasons why foreign-born faculty may seek work in the US, as reported by Shkolnikov (1994) and satisfaction with workload similar to that reported by Lin, Pearce, and Wang (2009). Since effort put forth for work tasks may be related to satisfaction, future studies may wish to examine this issue more thoroughly, examining satisfaction by gender, rank, or tenure status.

Results in Table 4 show that those faculty members who are foreign-born and married report higher levels of recent research productivity than US-born and unmarried peers. The findings on country of birth are consistent with that reported by Levin and Stephan in that individuals making contributions to S&E in the US are disproportionately drawn from the foreign born (Levin & Stephan, 1999; Stephan & Levin, 2001). It is most likely that faculty who are working at US institutions are the 'cream of the crop' and have very high research and/or technical skills. The relationship between career and recent research products confirms the notion of cumulative advantage (Creswell, 1985; Levin & Stephan, 1999). The finding that younger faculty produce more written products may be related to the intensity of scholarly output required for promotion and tenure, competition among personal roles and/or other reasons summarized by Levin and Stephan. It is also likely that faculty who have achieved tenure continue to publish, but may do so at a slightly lower level, compared to the years leading up to promotion and tenure.

Institution officials concerned about college rankings also realize that positive image and peer assessments may correspond with expanded visibility, revenues, and programs, which may in turn produce higher levels of knowledge-based research (O'Meara, 2007). It is likely that officials in doctorate-granting institutions intentionally apportion funds to research so that research faculty can have ample facilities and equipment. The luxuries of better facilities and equipment, however, come with the expectation for more scientific research and products. The culture of science and engineering disciplines encourages, or in some cases demands, extensive attention to external grant support, publications, and patents. These achievements are often accomplished better through collaboration, and regardless of gender or rank, collaboration and mentoring can be helpful. Lee (2004) reported high levels of collaboration for scientists, but also found that foreign-born faculty are more likely to have fewer collaborators and fewer co-authors than US-born faculty. Work with peers is also important in other university functions such as participation in faculty governance. If faculty members do not have extensive language or social skills to interact well with peers, they may not get involved in department or campus committees, and this may impact policy decisions made through governance bodies such as faculty senate.

Model Two in Table 4 indicates that female faculty in S&E fields were producing approximately the same number of scholarly written products as their male peers. This finding is in contrast with earlier work by Bellas and Toutkoushian (1999), Perna (2005), and Long (2001) who reported that women were less productive, but is consistent with the more recent report by the National Academy of Science (2010). Perhaps the current finding of greater gender equity heralds the prediction of Etzkowitz, Kemelgor, & Uzzi (2000) who posit that as more women enter the academic and workforce pipeline, gender gaps in occupational participation, advancement, compensation, and retention may disappear. Today's institutional policies, social expectations, and women's level of confidence may have advanced to enable female faculty to find equity in their careers and, in particular, in academic research productivity. Just like men, women faculty who earn tenure or tenure-track in doctoral universities have shown high levels of knowledge, skill, and competence when hired, and it is very possible that today's women faculty are as successful in their career as their male peers. However, discipline and culture within one's department are also important, and because women faculty are not well represented in some S&E fields, additional study in the trends in research productivity by gender may provide additional insight. For example, when examining earned doctorate trends in science disciplines over a 12-year period, Kulis, Sicotte, and Collins (2002) found that even after controlling for differences across fields, women had enhanced odds of holding faculty positions in biological and health sciences, but poor odds for positions in physics and astronomy, earth sciences, and agricultural sciences.

The finding from the multilevel analysis that satisfaction did not contribute significantly to productivity is consistent with descriptive findings in Table 3. Based on responses to this survey, S&E faculty appear, overall, satisfied with their work. Pfeffer and Langston (1993) reported that satisfaction is positively related to productivity, but instead of true cause and effect, it might simply be that "productive people are more satisfied as a consequence rather than that satisfaction causes productivity." (p. 395). In light of social exchange theory (Cotterrell, Eisenberger, & Speicher, 1992; Shore & Shore, 1995), those who are more satisfied with their academic work and institutional setting are more productive makes sense. Social exchange theory affirms that individuals put more effort into what they like and findings herein parallel these notions. However, cultural attitudes toward work and motivation to succeed may also be contributing to productivity. Perhaps foreign-born faculty have been enculturated with high work ethic or

standards that contribute to productivity differences. In general, immigrants choose to work longer hours than natives (Borjas, 1994, 2006;Carliner, 1980;). Differences in work levels may also be due to individual motivation. Espenshade and Rodrigues (1997) reported this to be true, due in part to foreign students' legal status with H1 or J1 visa and the difficult and lengthy process required to change their status. When foreign-born individuals move to the US, they may feel they must compensate for opportunity and costs incurred, and thus motivated to succeed. The subtle nuances of satisfaction, motivation, and attitudes toward work prompt the call for additional study of these issues and their relationship to research productivity. A complementary qualitative study in which select faculty are interviewed on attitudes toward work might strengthen current findings.

As would be expected, the amount of funds apportioned to research played a very strong role in research output. This finding makes sense in that faculty members who have state-of-the-art equipment and facilities, and the time needed to devote to research (therefore lower teaching loads) are likely to be more productive. Other institutional variables included herein did not yield further insight; results indicated that mean faculty to student ratio, level (extensive vs. intensive), nor type (private vs. public) of institution played a role in research production. Although the variance statistic for the HGLM model at level two was somewhat small, it was significant at the .01 level, and thus indicates difference across doctorate-granting institutions in this sample. Future studies may wish to incorporate other measures of the institutional environment such as departmental mentoring that might affect research productivity.

## Limitations

Findings presented herein apply to full-time tenured and tenure-track S&E faculty in doctoral universities and do not generalize to non-S&E, part-time and non-tenure track faculty nor those in two-year, baccalaureate and master's level institutions. These findings examine important scholarly products, but do not include all research such as performances and exhibitions as well as many aspects of teaching such as advising, mentoring, and supervision with dissertation. In addition, analyses presented herein do not take into account faculty effort put forth on advising and public service. While these are important functions for many faculty members, this analysis was intended to focus on research production, and thus only included faculty for whom research was a significant part of their workload.

Minimal findings related to instruction may also be due to the nature of faculty roles with research. Since discovery-based knowledge is emphasized at doctoral institutions, teaching and student credit hour production are emphasized to a lesser degree. Further, a majority of foreign-born faculty in this study reside within the engineering, physical, and life sciences disciplines, and may have been hired primarily for their research skills, with less time spent in the classroom. Since the focus of this study is research productivity, it does not seek to explain faculty effectiveness related to instructional duties.

Unfortunately, the dataset did not readily offer variables to address faculty motivation. It is acknowledged that individual motivation may indeed play a role in research productivity. For all workers, high productivity may be due to embedded cultural and/or family standards for strong work ethic that affect some immigrant groups more than others (Harrell, 1985; Taylor & Stern, 1997). Foreign-born faculty may also be motivated to work in the US for access to better research facilities, a larger relevant information base, economic opportunities, and better living conditions (NSF Press Release 07-073; Shkolnikov, 1994) or because of one's legal status and temporary nature of the H1 visa (Espenshade & Rodriguez, 1997). Motivation for foreign-born faculty working in the US may also be due to need to gather income and/or skills so they can return home for a desired job in their native land (Saxenian, 1999). Future studies may wish to include a measure of motivation to control for this important construct.

Analyses presented herein employ Poisson modeling which assumes that mean scores and variances are equal. If means or variances were not equal, it is possible that standard errors may be inflated and may result in incorrect significant findings. The HLM software does not enable the researcher to employ a negative binomial model, but use of this model may provide additional insight and possible validation of results from the current Poisson model.

While variation across institutions was statistically significant in all models, results from the multilevel models show little difference by institution type (public vs. private). Because the opportunities and expectations for research productivity are not the same for bachelor's and master's institutions, only faculty from doctoral-granting institutions were included in this study. Further study to include other facets of institutional environment that are not

available in this data set, such as average number of research products by department, opportunities for collaboration, and mentoring may strengthen the findings for the effects of institutional variables on research productivity. Analyses presented herein examine factors that influence productivity, but do not imply cause and effect. In addition, it is acknowledged that all data is captured from a self-report survey. In general, however, self-report data is purported to be reasonably accurate (Tourangeau, Rips, & Rasinski, 2000). While analyses presented in the multilevel model represent a number of important individual and institutional characteristics that may contribute to research productivity, an important next step would be to include additional interaction effects. For example, examination of interactions between foreign-born status, rank, and sub-disciplines within S&E may provide additional insight.

## Implications

Greater understanding of foreign- and US-born faculty scholars and variables that contribute to their research productivity is important to ongoing success of faculty members as individuals as well as for institutional improvement. In addition to educational benefits for faculty and students, institutional prestige and economic benefits are realized through knowledge production and new discoveries that come from faculty research. Institutions and the surrounding communities benefit by incorporating 'brain gain' talent with expertise and multiple perspectives into campus that create innovation, creativity, enhanced student learning, and even understanding of foreign cultural issues and policy.

Institution officials concerned about college rankings also realize that positive image and peer assessments may result from higher levels of research funding and knowledge-based research. Decreased state funds will continue to prompt faculty to seek external sources for grant funds. Especially for tenured and tenure-track faculty, policies for promotion and tenure may more strongly emphasize research and not teaching or service. If this is the case, it is possible that faculty will devote more time and effort to research, perhaps leaving teaching and service duties to adjunct instructors. Such a tiered system would not benefit the overall mission and goals of research universities today, and may be especially detrimental to flagship institutions that play an important role in service to the state. As well, master's-level institutions are cautioned to monitor increased expenditures

on research, knowing that efforts and funds may be shifted away from teaching and service activities.

Faculty members who are productive researchers may also serve as role models for students in the classroom, laboratory, and other campus-based activities. Faculty often carry ideas gleaned from their research into the classroom, and this can bring classroom learning to life. In this capacity, faculty as instructors are sharing the most up-to-date thinking and demonstrating positive mentoring practices to students. Such practices may move students to consider additional study and/or academic research positions as a career option. To ensure a continued effective balance between faculty roles in teaching, research, and service, institutional leaders must consider the appropriate balance that is right for each institution, being mindful that movement away from the balance has consequences for student learning and public service.

While the balance across institutional missions must be maintained, it is acknowledged that economic benefits to both the institution and the community are realized through knowledge production and new discoveries. Especially for research universities, this central mission prompts faculty to apportion some, or perhaps the majority of time, in their quest for new knowledge. This is particularly true for S&E faculty who depend heavily on extramural funding. Successful grant acquisition requires not only scientific knowledge and skill but also the ability to communicate effectively in writing, and perhaps verbally in presentations to potential grant agency officials. Relatedly, successful grant acquisition is often accomplished through collaboration. Lee (2004) reported high levels of collaboration for scientists, but also found that foreign-born faculty are more likely to have fewer collaborators and fewer co-authors than US-born faculty. Work with peers is also important in other university functions such as participation in faculty governance. If faculty members do not have extensive language or social skills to interact well with peers, they may not get involved in department or campus committees, and this may impact policy decisions made through governance bodies such as faculty senate. In addition to collaboration within one's department, some S&E faculty members collaborate with faculty in other departments or interdisciplinary research centers. Corley & Gaughan (2005) report that in some science and engineering fields, approximately 40% of faculty are affiliated with university-based research centers. Collaboration in research centers likely brings together a diverse set of faculty who may have different expectations

for teaching, acquiring grants, and promotion and tenure (Bozeman & Boardman, 2004). Especially if involved in research centers or other interdisciplinary work, faculty members will need social and verbal skills suitable for such work with others. In addition, university officials may need to determine if current academic policies and expectations are appropriate for faculty highly involved in interdisciplinary work. Policy revisions may be needed to address the different expectations across departments for teaching, acquisition of grants, and overall research productivity.

The increase in the number of foreign-born scholars to US institutions has implications for international travel, study, long-term employment, and US visa policies. While the US nation was built on core values of diversity and inclusion, US immigration officials and policies must find a balance in accommodating international visitors and those who wish to become long-term residents. US postsecondary education is more globally-connected than at any time in our history and leading-edge academic work will occur with scholars who share knowledge and work collaboratively across the world. Future visa policies, including limits on the number of international scholars that are able to work for a specific period of time or seek permanent status may affect overall knowledge production of S&E faculty, and thus should be monitored by institutional officials.

Stephan and Levin (2001) describe the 'positive spillover' (from an economics perspective) that can result from larger foreign-born scholars, saying that the US has benefitted from the educational benefits made by other countries. It is likely that the entry of foreign born faculty will benefit the growth of US's human capital by improving US productivity and increased contributions to scientific innovation (Johnson & Regets, 1998; Skolnikoff, 1993). It is also possible that foreign-born faculty provide cheap labor. Since satisfaction with salary was the lowest measure of satisfaction (for both US- and foreign born, but foreign-born even lower), it is important that officials monitor labor and salary trends to ensure that large gaps between groups of faculty do not occur.

Findings herein may also have implications related to education and training of future graduate students and postdoctoral researchers. Hunt (2009) found that immigrants who first entered the US on student/trainee visa or temporary work visa had a large advantage over US natives in wages, patenting, writing books or papers for publication, and presentations at

conferences, primarily due to advantages associated with US postsecondary degree completion. Becoming familiar with the culture, both the country and the institution attended for graduate education, is critical in future research production, and perhaps those who learn the expectations and indirect expectations early are best positioned for later success. Just as we teach graduate students and postdoctoral researchers how to use equipment, we also need to ensure their understanding of how to verbally communicate, work with others, and think in all ways like a successful scientist. Committed institutions may wish to offer more seminars or other information sessions for faculty who mentor or for students on topics related to interpersonal interactions and effective communication. Perhaps, university-sponsored training sessions could be used to fulfill some requirements for scholars who wish to seek permanent visa status. In addition, it is likely that foreign-born faculty who came to the US from English-speaking countries or countries with similar cultural attitudes would likely have less difficulty in assimilating, due to language and/or cultural similarity. This current study did not examine in which country faculty earned their terminal degree or postdoctoral training, but additional study on faculty research productivity that includes information on the country or region of training or measure for similarity to the US language and culture are encouraged.

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