PATHWAYS VS. PIPELINES TO BROADENING PARTICIPATION IN THE STEM WORKFORCE

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This paper examines why women and minorities are underrepresented in science research careers. Millions of dollars of support over the years have been expended to remedy the underrepresentation of women and minorities in different science, technology, engineering, and mathematics (STEM) disciplines. An underlying premise of virtually every major intervention designed to increase the representation of women and racial and ethnic minority group members in STEM careers is that there exists a dominant pipeline toward those careers. The premise is that there is a conventional sequence of educational and training procedures for a specific career profile, and that such a sequence is effective in producing the desired results of increased representation of underrepresented groups. An alternative model—the pathways model—posits that there are multiple routes toward the required training for science careers and that the underlying problem is not the undersupply of graduates in science but barriers that undervalue these alternative routes taken by women and minorities. This paper tests the hypothesis that the pipeline metaphor is the correct representation of the production of increased diversity, using the chemistry profession as the case study. Using data from the Integrated Public Use Microdata Series–Current Population Survey (IPUMS-CPS) March Supplement for the period 1968–2012, we estimate post-baccalaureate (supply-side) effects and wage impacts (demand-side effects) on the relative presentation of women and minorities among those employed as chemists. We find large differences across racial, ethnic, and gender groups. We find very limited evidence to support the supply-side argument. The responsiveness to demand-side factors tends to be larger for minority group members than for others, suggesting that the pipeline model is inadequate for explaining underrepresentation in all professions. Finally, we show that women and minorities are underrepresented at different critical transition points from high school to college to graduate school to the workforce.

KEY WORDS: pipeline, pathways, underrepresentation, women, minorities, chemists, education, STEM, science and technology

1. THE PROBLEM OF UNDERREPRESENTATION

Women and minorities are generally underrepresented in science research careers (United States General Accounting Office, 2005). Significant underrepresentation is found in different science,
technology, engineering, mathematics, and medical sciences (STEMM) disciplines (Varki and Rosenberg, 2002; Maton et al., 2006; Andriole et al., 2008; Andrews, 2002; Fang and Meyer, 2003). Underrepresentation is found among college and university faculty in the sciences (Nelson, 2007), chemistry professionals (Nelson, 2001a; Kuck, 2005), and engineering professionals (Atman et al., 2010; Slaughter and McPhail, 2007). There also exist significant disparities in success in STEM fields as measured by such indices as National Institutes of Health (NIH) awards (Ginther et al., 2011).

A wide array of explanations has been offered for the underrepresentation of women and minorities in the STEM workforce and/or among those majoring in STEM fields. These explanations include: differences in interest in science and mathematics (Blickenstaff, 2005; Ferreira, 2003; Viadero, 2009); differences in opportunities to take advanced science and mathematics courses in middle school or high school and prepare for college-level science coursework (Carmichael et al., 1993; Cooper et al., 2005); an absence of role models, mentors, and academic support systems (Lawrence et al., 2005; Leggon and Pearson, 2009); an absence of a critical mass of women or minorities in certain STEM fields (Pearson, 1985; Mullen and Baker, 2008; Sharpe and Sonnert, 1999); and discriminatory barriers (MacLachlan, 2006).

Related explanations for underrepresentation of women and minorities in STEM fields include: differences between family and career paths (Rosser and Taylor, 2009; White, 2005; Andrews, 2002; Ware and Lee, 1988); a lack of role models (Andrews, 2002); perceptions of inferiority (Andrews, 2002); negative environments (Chang et al., 2011; Oseguera, et al., 2006; Barr et al., 2007); and lack of professional networks (Rosser and Taylor, 2009).

These explanations have helped to inform interventions that have received millions of dollars of support over the years. Funded by NIH, NSF, other government agencies, and private foundations, these interventions have sought to remedy the skills deficits, the absence of role models, the opportunities for exposure to research while in high school or college, and to help increase the supply of applicants and matriculates into graduate-level science programs. In economic parlance, the interventions focus on the supply side of the underrepresentation problem.

A core underlying premise of virtually every major intervention designed to increase the representation of women and racial and ethnic minority group members in STEM careers is that there exist a dominant pipeline toward those careers. A pipeline is understood to be a favored or privileged route or channel toward entering a profession. Because this is the main source of channeling members of majority groups into the profession, it is expected that others also follow these routes. The routes themselves are favored not necessarily because they are the most efficient or equitable entry points to the profession. Rather, these routes are favored because they work and have worked for the dominant group.

Whether the intervention is designed to increase the initial pool of persons in the pipeline, to move them successfully along the pipeline, or to retain them within the pipeline once they have decided on STEM careers, the interventions all share a common underlying premise. The premise that there is in fact a conventional sequence of educational and training procedures for the specific career profile—e.g., chemical careers—and that such a sequence is effective in producing the desired results of increased representation of underrepresented groups. Thus, aside from the assumption that underrepresentation essentially is a supply-side problem is the premise that the institutional mechanism determining supply is a traditional or dominant pipeline.
2. THE PIPELINE MODEL

A typical application of the conventional pipeline model is found in the analysis of the production of clinical physicians who engage in medical research. For decades the medical research community has recognized the need for more clinicians who engage in research. Wyngaarden (1979) brought attention to the dearth of clinical researchers, and by the late 1990s, the number of physicians applying for research funding at NIH was declining precipitously (Rosenberg, 1999). As a result, numerous programs were funded at medical schools to increase the participation of emerging clinicians in research. These include the Scholars in Clinical Science Program at Harvard Medical School, which is designed to lower barriers to scientific investigation for clinicians who want to engage in research (Wolf, 2002), a research scholars program at Howard Hughes Medical Institute (Fang and Meyer, 2003), and similar programs at the University of Tennessee Health Services Center and Vanderbilt University (Solomon et al., 2003), and Mount Sinai School of Medicine (Zier and Stagnaro-Green, 2001).

These efforts all share a common analytical model. They presume a pipeline model of developing physician-scientists, where existing students in medical school are given incentives and encouragement to engage in research. The students are already in the pipeline for the production of clinical physicians. The programs augment skills and foster creativity, allowing the students to engage in productive research activities and to conceptually shift to an alternative pipeline that produces research scientists. Moskowitz and Thompson (2001) provide a clarifying illustration that explains the process of getting students through the pipeline from elementary school years through to the MD, or alternatively, to the PhD in a biomedical research field. The understanding is that once in the core clinical medicine pipeline, mechanisms exist to redirect institutional resources to assure the production of not only physicians but also biomedical researchers.

There are two important issues missed in this description or model of the production of clinical physicians versus biomedical researchers. First, there is no indication as to any differential effect of the programs mentioned on women versus men or on white students versus minority students. Second, there are no alternative pathways assumed for increasing the pool of physician-researchers within this pipeline model. At least implicitly, then, the production of women and minority research scientists and clinical professionals is deemed to be suboptimal outside of the dominant pipeline.

In the engineering disciplines, several studies have revealed the hindrances and success factors encountered by students as they endeavor to enter the field outside of the conventional pipeline. Atman et al. (2010) surveyed and interviewed more than 5,400 engineering college students during the years 2003 through 2010. The resulting report—Enabling Engineering Students Success—focuses on undergraduate engineering education, examining the efficacy of pipeline methods on getting undergraduates successfully employed in engineering fields. The authors of the report acknowledge that the pipeline model may be flawed and that a pathways approach that is not “one size fits all” is a superior strategy.

The National Academy of Engineering and the National Research Council jointly published their report in 2005 entitled, Enhancing the Community College Pathway to Engineering Careers. This report validates the hypothesis that community colleges are a viable alternative pathway to careers in engineering compared to the traditional four-year institution route. The authors of the report find it imperative that communications and linkages (including partnerships) be created or strengthened between two-year and four-year institutions to ensure that students obtain
the skills required for engineering jobs throughout their college career. The handoff from a two-
year college to the four-year college or university could allow for a deficit in skill sets, if such
communications were weak or nonexistent. So, even here the vision is to move underrepresented
groups from alternative pathways onto the dominant pipeline.

A quick illustration to underscore why pipeline models might be insufficient for understand-
ing racial/ethnic/gender differences in employment in STEM fields comes from looking at the
impacts of advanced placement (AP) coursework. In the conventional pipeline model there are
critical junctures or leakage points that help to explain why some people persist and others drop
out of the STEM production cycle. Taking AP coursework in high school is understood to be one
of those critical junctures.

Table 1 shows the results from the 2000 NELS88 (National Education Longitudinal Survey)
follow-up of the probabilities and conditional probabilities of majoring in a STEM field in col-
lege. In the first panel the table reports the probability of a STEM major for persons who were
in the 8th grade in 1988. It is 8.16 percent for white males, 6.39 percent for white females, 3.38
and 2.83 percent for Latinos and Latinas (respectively), and 4.31 percent and 5.37 percent for
black males and females (respectively). The lowest percentages are for American Indians/Alaska
Natives: males at 1.47 percent and negligible female presence in STEM. These low numbers
reflect, in part, the low probabilities that African Americans, Hispanics, and American Indians
have for attending college at all. By way of contrast, the conditional probabilities of majoring
in STEM fields for persons taking AP courses in high school are considerably larger for women
and underrepresented minorities, and there is some narrowing of the gap between white males
and other groups. But whether a pipeline-based policy intervention of enrolling more females
and minorities in AP courses is a promising strategy for increasing STEM majors depends on
whether the entire distribution shifts when one takes AP courses or whether only the upper tail of
the distribution is reproduced when one focuses only on students taking AP courses.

Table 2 reconfigures the data from Table 1 to offer a different perspective. It shows that for
blacks and Latinos there is virtually no difference between the conditional probability of majoring
in a STEM field, given AP courses in high school and the conditional probability of majoring in a
STEM field given that one attends college. In fact, for American Indians the conditional probabil-
ity of a STEM major is lower if one takes AP courses than the conditional probability of a STEM
major given that one attends college. Thus the conventional wisdom predicting a pipeline from
AP coursework to STEM majors does not appear to match observed distributions of outcomes.

This is akin to the selection problem in conventional regression analysis. The difference is that here we
actually are able to observe the entire distribution and as such there is no unobserved selection. We know
both who took AP courses and who did not, and we observe everyone who enters college. The advantage of
mapping the entire distribution is to be able to detect directly whether the improved probabilities in Table 1
are due to a shifting of the entire distribution or simply the creaming of the top portions of the distribution.
These differences can be attributed to differences by gender. The conditional probability of majoring in
STEM for black males is lower for those who take high school AP courses than that for all black males
who attend college. Black females who take AP courses have higher conditional probabilities of majoring
in STEM fields than others.

Because these data sets are longitudinal, calling them “old” or “outdated” is a misnomer. The people in
the NELS88 data were 12–14 in 1988, which means they reflect the high school and college experience of
persons who, in 2011, are now 35–37 years of age. The last follow-up was in 2000 when the participants
were 24–26. The people in the PPYP data set are a sample of physicians who were born in 1952 or later
and who completed residency training between 1986 and 1989.
### TABLE 1: Probability of STEM major and conditional probability of STEM major in college/university

<table>
<thead>
<tr>
<th></th>
<th>% of STEM students of all students</th>
<th>% of STEM students of all AP students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>White, not Hispanic</td>
<td>8.16%</td>
<td>6.39%</td>
</tr>
<tr>
<td>Black, not Hispanic</td>
<td>4.31%</td>
<td>5.37%</td>
</tr>
<tr>
<td>American Indian or</td>
<td>1.47%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Alaska Native</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian or Pacific</td>
<td>16.14%</td>
<td>14.25%</td>
</tr>
<tr>
<td>Islander</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic or Latino</td>
<td>3.38%</td>
<td>2.84%</td>
</tr>
<tr>
<td>Total</td>
<td>7.58%</td>
<td>6.06%</td>
</tr>
</tbody>
</table>

Source: Authors’ calculation from NELS:88

### TABLE 2: Gender differences within race/ethnicity in probabilities of college, STEM major given college, and STEM major given AP coursework

#### P (college/hs)

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Males</th>
<th>Females</th>
<th>M/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asian</td>
<td>88.35</td>
<td>87.01</td>
<td>89.63</td>
<td>0.97</td>
</tr>
<tr>
<td>Hispanic</td>
<td>67.83</td>
<td>65.52</td>
<td>69.83</td>
<td>0.94</td>
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<tr>
<td>Black, not Hispanic</td>
<td>67.68</td>
<td>62.16</td>
<td>72.05</td>
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<tr>
<td>White, not Hispanic</td>
<td>74.87</td>
<td>71.75</td>
<td>77.78</td>
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</tr>
<tr>
<td>Native American</td>
<td>52.38</td>
<td>46.15</td>
<td>56.76</td>
<td>0.81</td>
</tr>
</tbody>
</table>

#### P(STEM/college)

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Males</th>
<th>Females</th>
<th>M/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asian</td>
<td>32.95</td>
<td>37.01</td>
<td>29.20</td>
<td>1.27</td>
</tr>
<tr>
<td>Hispanic</td>
<td>20.69</td>
<td>23.69</td>
<td>18.26</td>
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<tr>
<td>Black, not Hispanic</td>
<td>24.55</td>
<td>27.68</td>
<td>22.42</td>
<td>1.23</td>
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<tr>
<td>White, not Hispanic</td>
<td>21.44</td>
<td>27.14</td>
<td>16.54</td>
<td>1.64</td>
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<tr>
<td>Native American</td>
<td>18.18</td>
<td>29.17</td>
<td>11.90</td>
<td>2.45</td>
</tr>
</tbody>
</table>

#### P(STEM/hs-AP)

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Males</th>
<th>Females</th>
<th>M/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asian</td>
<td>38.85</td>
<td>42.36</td>
<td>35.88</td>
<td>1.18</td>
</tr>
<tr>
<td>Hispanic</td>
<td>20.59</td>
<td>23.93</td>
<td>17.51</td>
<td>1.37</td>
</tr>
<tr>
<td>Black, not Hispanic</td>
<td>24.09</td>
<td>22.61</td>
<td>25.16</td>
<td>0.90</td>
</tr>
<tr>
<td>White, not Hispanic</td>
<td>24.62</td>
<td>31.06</td>
<td>18.83</td>
<td>1.65</td>
</tr>
<tr>
<td>Native American</td>
<td>13.64</td>
<td>14.29</td>
<td>13.33</td>
<td>1.07</td>
</tr>
</tbody>
</table>

Source: Authors’ computation from NELS88. STEM majors defined as engineering, biological sciences (biology, botany, zoology, biochemistry, all others), physical sciences (physics, chemistry, earth science, all others), mathematics, statistics, psychology, anthropology/archeology, economics, interdisciplinary sciences, computer programming, and data processing technology.
3. PIPELINES VERSUS PATHWAYS

A largely untested assumption about pipeline models is that dominant pipelines toward successful careers are the same for women and underrepresented minorities as they are for white males. But yet, there is a broad literature from educational policy that suggests that there are alternative pathways to post-baccalaureate education and that these alternative pathways are disproportionately pursued by racial and ethnic minority group members and to some extent women, especially women with children (Turner et al., 1999). This literature on alternative pathways mirrors the dual labor market literature that differentiates between markets (a) where there is a vertical trajectory to employment characterizing the dominant movement from entry to successful careers, and (b) where there are multiple horizontal paths, entry and exit points that largely exist below the entry level of the dominant labor market (Doeringer and Piore, 1971).

As such, there has evolved what can be termed the pipeline versus pathways metaphor to describe the underrepresentation of women and racial and ethnic minority groups among tenure-track faculty in major universities and researchers in government research labs and think tanks. The concept is widely referenced. The term is a part of common parlance, and it has appeared in numerous government publications, but in fact the theoretical underpinnings are poorly understood.

One central feature of the pipeline model is that the production of the most highly trained members of a profession, e.g., tenured faculty at research universities, is the outcome of a structured educational process resulting in the award of the PhD. Turner and Myers (1999) and Turner et al. (1999) produced a survey of attitudes and beliefs about the underrepresentation of women and minority faculty among member institutions of the Midwest Higher Education Consortium (MHEC). They established that one widely held belief among university vice presidents and provosts was that the cause of the underrepresentation of women and minority tenure-track faculty across various fields was the low supply of women and minorities with PhDs in those fields. The solution, implicitly, was to increase the number of women and minorities in the pipeline to research careers in order to produce more PhDs, in order to produce more qualified faculty.

Myers and Turner (2004) contest this conclusion. They establish that this widely held belief or perception was not consistent with national census data showing (a) a rapid increase in the supply of women and minorities with PhDs in the fields where there were large disparities in hiring and promotion and (b) the weak statistical relationship between PhD recipiency and faculty representation. Thus Myers and Turner’s work challenged the view that the solution to the problem of underrepresentation among faculty was merely to increase the number of women or

*We used the harmonized version of the IPUMS-CPS to create a variable called “post-baccalaureate” education to account for the differing measures of graduate education in the CPS from the 1960s to the present. Prior to 1992, the codes used for graduate educational attainment included 6+ years of college. From 1992 until the present, the coding was master’s degree, doctorate degree. We define “post-baccalaureate” education to be equal to 6+ years of education in the years prior to 1992 and master’s degree or doctorate degree in 1992 and beyond.

This metaphor is widely adopted in the social science literature. The phrase itself, pipelines versus pathways, is found prominently in a broad array of publications. A detailed search of Google Scholar for social science publications between 2005 and 2011 produces 7,521 hits for the phrase “Pipelines versus Pathways.” A search of the science and engineering literature produces 2,780 hits.
minorities in the pipeline. In their research, Myers and Turner (2004) showed that attitudes and beliefs about the lack of qualifications and the “chilly climate” in the research enterprise often overshadowed the inadequate supply problem. Moreover, the analysis of data on wages and employment showed that market wages often exerted a larger impact on the relative representation in faculty positions than supply-side factors (such as the supply of PhDs or those in the pipeline).

4. THE CASE OF CHEMISTRY

The chemistry profession is a good case in point. This is a profession that as recently as 40 years ago was dominated by white males but over time has since become much more diverse. In recent years, the American Chemical Society has elected African American, American Indian, Hispanic, and female presidents (Cecilia et al., 2006). As we will demonstrate in this paper, chemistry has become more diverse, but improvements in the relative representation of women and minorities has been uneven. The chemistry profession is a large and contentious one where there are many continuing disagreements over the causes and consequences of highly visible changes in its racial and gender makeup.

One of the contentious issues is the issue of barriers to entry and movement along the pipeline. There is a widespread perception that despite years of apparent improvement in diversity in the chemistry profession, the academic profession continues to manifest institutional barriers limiting opportunities for women and minorities, as evidenced by the dearth of female and minority chemistry faculty at top research universities (Nelson, 2001b; Kuck, 2005). Studies of the causes of the faculty underrepresentation point to key barriers at critical points along the faculty pipeline. Greene et al. (2010) find that female chemistry faculty believe that they are paid less, receive less recognition for their scholarly work, are allocated less space and secretarial assistance, and garner less respect from students than male faculty. The respondents in one survey reported that they had heavier teaching loads and less time to perform academic research in comparison to the men in their faculty departments (Greene et al., 2010). The result is a continued underrepresentation of female chemistry faculty at top research universities, despite a putative rise in the representation of females in the chemistry profession (Stockard et al., 2008).

The timing of the representation of female faculty in the chemistry profession can be linked to major civil rights and related events. For example, the path-breaking Rajender Consent Decree of 1980 marked a turning point in litigation regarding discrimination against women in hiring, promotion, salary, and tenure among faculty members (Kholstedt and Fischer, 2009). Race-conscious hiring in public institutions (along with race-conscious admissions and public procurement and contracting) was threatened by litigation and numerous anti-affirmative-action ballot initiatives across the country during the 1990s (Myers, 2011).

Other factors that allegedly contribute to the underrepresentation of women in sciences include: (1) biological differences between both genders; (2) a lack of science education and preparation among girls in comparison to male students; (3) “girls’ poor attitude toward science and lack of positive experiences with science in childhood”; (4) the substantial lack of women role models in science; (5) irrelevancy of science curriculum to girls; (6) science curricula that foster the interest of science in boys more than girls; (7) an unfriendly “chilly climate for girls/ women in science classes”; (8) pressure for women/girls to assume traditional gender roles; and (9) an overarching masculine view of the sciences held by males in the profession (Blickenstaff, 2005).
Johnson (2007) contends that the historic structure of science teaching—particularly of chemistry—conflicts with the best learning styles of minority females, who benefit more from interactive teaching strategies than traditional large lecture approaches. In an examination of chemistry textbooks, King and Domin (2007) show that images generally do not reflect racial or ethnic diversity, further affecting perceptions about chemistry as a professional goal. Towns (2010) reports that there were no African American female full professors at the top 100 chemistry departments in 2007 and only one in 2008.

The chemistry profession encompasses more than just chemistry teachers at colleges and universities. Diversity interventions designed to increase the supply of women and minority chemists are likely to affect not only employment in academia but also employment in private sector, public, and nonprofit research laboratories.

To understand this broader context of chemistry employment one can measure (under)representation by race, gender, and ethnicity from 1969 to 2012. Two key impacts on representation in the chemistry profession can be explored: (a) the effects of expected wages and (b) the effects of post-baccalaureate education. A strong finding of impacts of post-baccalaureate education on representation ratios would be consistent with a pipeline (or supply-side) model. We will demonstrate below that there have been episodic changes in the representation of women and minorities in the chemistry profession. Post-baccalaureate (supply-side) effects and wage impacts (demand-side effects) differ across groups, but the responsiveness to demand-side factors tends to be larger for minority group members than for others, suggesting that the pipeline model is inadequate for explaining underrepresentation in this profession.

5. DESCRIPTIVE EVIDENCE: CHEMISTRY

We use the Integrated Public Use Microdata Series–Current Population Survey (IPUMS-CPS) March Supplement to obtain information on employment as a chemist. We define chemist using the IPUMS-CPS codes: chemist, chemical technician, chemical engineer, chemistry instructor. We compute three-year moving averages for the years 1968–2009 in our aggregate analysis and restrict the sample to employed 18–60 year olds in the civilian noninstitutionalized labor force with at least two years of college (skilled workers).

The IPUMS-CPS data provide a uniform and consistent set of measures across years of variables included in the Census Bureau’s Current Population Survey (CPS), a national survey of more than 50,000 households used to measure key economic outcomes. The main set of variables included in the CPS data relates to employment, wages, and salaries, and labor force participation. The March Supplement includes a rich set of demographic variables, including age, educational attainment, and occupational classification. Because the data set includes information on both supply-side variables (e.g., educational attainment) and demand-side variables (wages and salaries), this data set is particularly useful for estimating the testing hypotheses about the determinants of underrepresentation in specialized science fields such as chemistry.

The chemistry profession has become more diverse. In 1968–1970, 90 percent of all persons employed in the United States as chemists, chemical engineers, chemistry teachers, or chemical technicians were white males. Another eight percent were white females. The remaining two percent were blacks and others. By 2007–2009, the profession had become very diverse. By 2007–2009, 48.7 percent of chemists were white males, 19.6 percent were white females, and
Asian, Hispanics, and blacks accounted for 18.5 percent, 5 percent, and 7.3 percent (respectively) of the total. These descriptive results show that the chemistry profession has become more diverse. The share of white males in that profession has declined while the share of all other groups collectively has increased. What these results do not show, however, is that the relative representation of women and minorities, surprisingly, has not increased uniformly. To understand this we need to introduce the concept of a representation ratio.

Representation ratios measure a group’s share of a profession relative to the group’s share of the population. When a group’s share of a profession equals its share of the relevant population base, then the representation ratio is equal to 1. When a group’s share of a profession is less than its share of the population base, the representation ratio is less than 1 and the group is deemed to be underrepresented in the profession. For the purposes of this paper, the relevant population base will be skilled workers, or those with two or more years of post-secondary education.

Figures 1–5 present three-year moving averages of representation ratios computed for white males, white females, Hispanics, African Americans, and Asians for the period of 1968–2012. The sample relates to individuals, 18–64 years of age, employed in the civilian noninstitutionalized labor force and with two years or more of education.\(^5\) We produce these figures using both weighted and unweighted data, confirming no anomalies related to sampling. These computations reveal dramatic episodic changes in the representation ratios for different groups. Figure 1 shows that the representation ratios for white males dropped from 1.61 in 1968–1970 to 1.37 in 1980–1982; they rose to 1.56 in 1999–2001; they dropped to 1.38 in 2010–2012. The long-term trend, as evidenced by the declining share of chemists who are white males, has been a drop in the overall representation ratios for this group. Among white females, the representation ratio rose from 0.2 in 1968–1970 to 0.65 in 1991–1993. After dropping to 0.43 in 2004–2006, it rose again to 0.59 in 2010–2012, still lower than it was in 1991–1993. Thus, white women saw dra-
FIG. 2: Representation ratio of skilled chemists, white females

FIG. 3: Representation ratio of skilled chemists, Hispanics

FIG. 4: Representation ratio of skilled chemists, African Americans
matic improvements in their relative representation among chemists from the late 1960s until the early 1990s but witnessed a relative deterioration in their representation before the recent recovery of their representation in the profession. Among blacks, representation ratios increased from 0.47 in 1968–1970 to 1.03 in 1980–1982, then dropped to 0.48 in 1990–1992, rose and then fell again to 0.72 in 2010–2012. Similar episodic changes are observed among other groups as well.

Table 3 reports the averages of the representation ratios over two time periods: 1968–1989 and 1990–2012. To put these representation ratios into perspective, Table 3 also reports the relative incomes and relative educational attainments of those employed in the chemistry profession. The relative incomes are computed as the ratio of the annual wage and salary incomes for those employed as chemists to the annual wage and salary incomes for all skilled workers. The relative educational attainment is the ratio of the percentage of chemists who have post-baccalaureate degrees to the percentage of all skilled workers who have post-baccalaureate degrees.

For white males, there was a ten percent drop in representation ratios, from 1.89 in 1968–1989 to 1.70 in 1990–2012. For white females the representation ratios increased between the two time periods from 0.33 to 0.57, or a 72 percent increase. Hispanic representation ratios dropped from 0.43 to 0.26, while black representation increased from 0.37 to 0.47 over the two time periods. Asian representation ratios rose from 2.43 to 3.27, reflecting a 35 percent increase over the two time periods.

Table 3 shows that the relative incomes of chemists are higher than they are for all skilled workers for each of the racial/ethnic subgroups. The ratios were higher in 1968–1989 vs. 1990–2012 for all groups except Hispanics, who experienced a 4 percent increase in relative incomes for chemists. Still, the income advantage of being employed as a chemist relative to being em-

\[ R_k^{\text{rel}} = \frac{\rho_k}{\beta_k}, \]

where the numerator is the share of chemists who are members of the \( k^{\text{th}} \) group and the denominator is the share of skilled workers who are members of the \( k^{\text{th}} \) group.
**TABLE 3:** Summary statistics on relative incomes, educational attainment and representation ratios, chemistry profession, 1968–1989 vs. 1990–2012

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<thead>
<tr>
<th></th>
<th>Mean income, chemists/mean income, skilled workers (1)</th>
<th>% with post-baccalaureate education, chemists/ % skilled workers (2)</th>
<th>Representation ratio, chemists (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>White males</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1968–1989</td>
<td>1.39</td>
<td>1.60</td>
<td>1.89</td>
</tr>
<tr>
<td>1990–2012</td>
<td>1.33</td>
<td>1.42</td>
<td>1.70</td>
</tr>
<tr>
<td>Percentage change</td>
<td>-4.63%</td>
<td>-11.35%</td>
<td>-10.08%</td>
</tr>
<tr>
<td><strong>White females</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1968–1989</td>
<td>2.06</td>
<td>1.81</td>
<td>0.33</td>
</tr>
<tr>
<td>1990–2012</td>
<td>1.82</td>
<td>1.48</td>
<td>0.57</td>
</tr>
<tr>
<td>Percentage change</td>
<td>-11.49%</td>
<td>-18.23%</td>
<td>71.71%</td>
</tr>
<tr>
<td><strong>Hispanics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1968–1989</td>
<td>1.68</td>
<td>1.76</td>
<td>0.43</td>
</tr>
<tr>
<td>1990–2012</td>
<td>1.75</td>
<td>1.16</td>
<td>0.26</td>
</tr>
<tr>
<td>Percentage change</td>
<td>4.13%</td>
<td>-34.07%</td>
<td>-38.98%</td>
</tr>
<tr>
<td><strong>African Americans</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1968–1989</td>
<td>1.68</td>
<td>1.91</td>
<td>0.37</td>
</tr>
<tr>
<td>1990–2012</td>
<td>1.59</td>
<td>1.33</td>
<td>0.47</td>
</tr>
<tr>
<td>Percentage change</td>
<td>-5.36%</td>
<td>-30.13%</td>
<td>26.43%</td>
</tr>
<tr>
<td><strong>Asians</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1968–1989</td>
<td>1.95</td>
<td>3.41</td>
<td>2.43</td>
</tr>
<tr>
<td>1990–2012</td>
<td>1.45</td>
<td>2.09</td>
<td>3.27</td>
</tr>
<tr>
<td>Percentage change</td>
<td>-25.86%</td>
<td>-38.73%</td>
<td>34.66%</td>
</tr>
</tbody>
</table>

Source: Authors’ computations from IPUMS-CPS March Supplement, 1968–2012

Note: (1) Mean wage of skilled chemists by subgroups/mean wage of skilled workers by subgroups. (2) Percent of skilled chemists with post-baccalaureate by subgroups/percent of skilled workers with post-baccalaureate by subgroups. (3) Representation ratio = (number of kth group skilled chemists/number of kth group skilled workers)/(total number of skilled chemists/total number of skilled workers).

Table 3 also reveals educational advantages of being employed as a chemist. The percentage of chemists who have post-baccalaureate degrees is from 1.16 times to 3.41 times as high as the percentage of all skilled workers with advanced degrees. All groups experienced a decline in the relative educational advantage among chemists. For example, among Hispanics, the ratio dropped from 1.76 in 1968–1989 to 1.16 in 1990–2012. Among Asians, the ratio dropped from 3.41 in 1968–1989 to 2.09 in 1990–2012.

In summary, those employed in the chemistry profession earn more than other skilled workers and they are better educated. White females, Hispanics, and African Americans are underrepresented in the profession, while white males and Asians have representation in the chemistry profession that exceeds their percentage of those employed in all skilled professions.
6. MODELING REPRESENTATION RATIOS

One way to understand the process by which the racial/ethnic/gender distribution of chemists has changed over time is to decompose the representation ratios. Representation ratios are a convenient way of summarizing across time the relative status of different subgroups in a profession. One of the convenient properties of representation ratios is that they can also be expressed in the form of probabilities of employment in a profession. These probabilities can then be estimated as a function of such key factors as post-baccalaureate educational attainment and expected wages.

Consider the probability $P$ of being a chemist and the probability $P^k$ that a member of the $k$th group is a chemist. Then the representation ratio for the $k$th group in the chemistry profession, $R^k$, is the ratio of $P^k$ to $P$:

$$ R^k = \frac{P^k}{P} = \text{representation ratio for the } k\text{th group} $$

Representation ratios greater than 1.0 indicate greater representation of the $k$th group in the profession relative to its share of the skilled population. Ratios less than 1.0 (minimum of 0) indicate the $k$th group has less representation as chemists than for the skilled labor force as a whole.°

Denote $s^k$ as the $k$th group’s share of chemists and $s^k$ as the $k$th group’s share of the skilled population. Thus, the representation ratio $R^k$ is given by

$$ R^k = \frac{P^k}{P} = \frac{\# \text{chemists}}{\# \text{skilled workers}} \quad \text{and} \quad \bar{P} = \frac{\text{overall mean probability of employment as a chemist}}{\text{overall mean probability of employment as a chemist}} $$

Denote $s^k(j)$ as the $k$th group’s share of chemists and $s^k$ as the $k$th group’s share of the skilled population. Thus, the representation ratio $R^k$ is given by

$$ R^k = \frac{\# \text{chemists}}{\# \text{skilled workers}} = \frac{\text{probability of employment as a chemist}}{\text{probability of employment as a chemist}} $$

These aggregate patterns can be decomposed by estimating the underlying probabilities that comprise the representation ratios. These underlying probabilities of being employed as a chemist can be estimated as a function of supply-side and demand-side factors. The pipeline metaphor for the production of chemists is a supply-side phenomenon. The pipeline represents the process of producing the output or supply of chemists. This process involves an extended educational

°In the aggregate, there are two identical ways of expressing the representation ratio: (a) the ratio of the $k$th groups’ mean probability of employment as a chemist to the overall mean probability of employment as a chemist, and (b) the ratio of the $k$th group’s share of chemists to the $k$th group’s share of the population.
training that culminates with a master’s or doctorate degree. This is certainly true for university professors and is increasingly the case for chemical engineers, chemistry instructors, and chemical technicians. A test of the hypothesis that there is a strong positive effect of post-baccalaureate education on the representation ratio for a given group provides support for the pipeline model. Below we test this hypothesis.

7. THE DETERMINANTS OF REPRESENTATION RATIOS

Representation ratios—and the underlying probabilities of being a chemist—depend on such factors such as age, education, citizenship, state of residence, public versus private sector, and industry along with post-baccalaureate education (supply-side factors) and expected wages (demand-side factors).

7.1 Post-Baccalaureate Education

To capture supply-side effects on the probability of being a chemist, we compute a measure of post-baccalaureate education equal to 1 if a respondent has a master’s or PhD degree or six or more years of post-baccalaureate education. Because of the timing of the production of education and its impacts on the labor supply, we interact this measure with a dummy variable for persons over 40 years of age. As we will show later, this lends to an interpretation of the coefficient on the post-baccalaureate variable as being the impact of education on the probability of being a chemist for persons under 40 (or where the interaction term is equal to zero).

7.2 Expected Wages

To capture demand-side effects on the probability of being a chemist, we estimate expected earnings in chemistry in year $t$ as the natural logarithm of wage and salary incomes for chemists in year $t-1$. We restrict each regression to skilled chemists to obtain the coefficients from year $t-1$ and apply these coefficients to characteristics in period $t$. This provides a measure of what individuals in year $t$ might expect to earn based on observations from the market demand for chemists in the previous period. Note that these predictions are not the actual wages received by a given worker. Rather, they are estimates based on the returns to workers in the previous year.

Details of this first-stage regression are available from the authors. Suffice it to say that the wage and salary income equation estimated in period $t-1$ for years 1968–2011 produces estimates of expected wage and salary incomes for chemists in the years 1969–2012. The wage and salary income equation is estimated as a function of age, squared age, education level, real GDP per capita, race/ethnicity, and region (west, south and northeast) at the first stage.

$^5$All of the files can be found at http://www.hhh.umn.edu/publications-video-roy-wilkins-center/pathways-vs-pipelines-JWMSE2015 under “Pathways vs. Pipelines to Broadening Participation in the STEM Work force,” 2015 data.

$^6$Research has shown that wages rise with experience, which is highly correlated with age. Over time, however, wages increase at a decreasing rate as a worker's productivity reaches a plateau. Therefore it is common practice to include both age and age squared in wage regressions.
7.3 Other Factors

In addition to post-baccalaureate education and expected wages, we hypothesize that the probability of being employed as a chemist depends on age, citizenship, employment in the public sector, oil sector, manufacturing, and interaction terms of age above 40 with public sector and post-baccalaureate education.

7.4 Probability of Employment as a Chemist

Table 4 reports the results of estimating a logistic model of the probability of being a chemist as a function of post-baccalaureate education, expected wages, and other factors for two time periods: 1969–1989 and 1990–2012. The motive for combining years is to increase the number of observations required for obtaining estimates in the model. The justification for the split in the sample at 1989 is that it was this time period when legal challenges to race-conscious affirmative action programs in such areas as public procurement and contracting reached the US Supreme Court. Public procurement and contracting affirmative action programs once mandated set-asides for women- and minority-owned enterprises, factors that arguably contributed to the expansion of employment opportunities for underrepresented groups in industries that are either government regulated or that bid on government contracts. The period after 1990 is sometimes called the “post–civil rights era” because it represents a time of retrenchment in support of direct public efforts designed to expand the supply of women and minorities in professional jobs.

The results reported in Table 4 include coefficient estimates for all skilled workers, for white males, white females, African Americans, and Hispanics for 1969–1989 and 1990–2012. Asian results are only available for 1990–2012 due to lack of coverage of Asians in the CPS data prior to 1990. There are positive coefficients on both the post-baccalaureate variable and the expected wage variable, although these coefficients are not uniformly significant at the 5 percent level. Negative coefficients are estimated for the over 40 variables, whereas positive coefficients are estimated for the industry and noncitizen variables.

The easiest way to interpret the coefficients on the post-baccalaureate variable, which is dichotomous, is to compute odds ratios. The odds ratio has the interpretation of being the multiple by which the employment odds in chemistry change when a person has post-baccalaureate education. Table 5 reports these odds ratios. Overall, for all groups, the odds in favor of being employed as a chemist were 2.67 times higher for recipients of post-baccalaureate education versus others from 1969 to 1989. The odds were 2.23 from 1990 to 2012. The odds for white males were 2.145 and 1.953 for the periods 1969–1989 and 1990–2012, respectively. By way of contrast, the odds for blacks were 3.580 and 1.910 for the periods 1969–1989 and 1990–2012, respectively. In short, post-baccalaureate education increased the supply of chemists but the effect was larger for blacks than for whites and other groups in 1969–1989. The effect, which was lower for most groups in 1990–2012, was about the same for blacks as for whites in the post–civil rights era.

7.5 Results

The conventional method for comparing the effects of independent variables measured in differing units (e.g., continuous versus dichotomous independent variables) is to compute elasticities. An elasticity is the percentage change in a dependent variable as a result of a small change in

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</tr>
</thead>
<tbody>
<tr>
<td>Sample</td>
<td>All White male</td>
<td>All White male</td>
<td>White female</td>
<td>White female</td>
<td>Hispanic Black</td>
<td>Hispanic Black</td>
<td>Hispanic Black</td>
<td>Hispanic Black</td>
<td>Hispanic Black</td>
<td>Hispanic Black</td>
<td>Hispanic Black</td>
<td>Hispanic Black</td>
</tr>
<tr>
<td>In[wage(t-1)]</td>
<td>0.220*** (0.0449)</td>
<td>0.233*** (0.0479)</td>
<td>-0.09914 (0.105)</td>
<td>0.0455 (0.0997)</td>
<td>0.928*** (0.190)</td>
<td>0.345* (0.209)</td>
<td>0.196 (0.145)</td>
<td>0.330** (0.132)</td>
<td>0.0802 (0.160)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-B degree</td>
<td>1.028*** (0.0617)</td>
<td>0.857*** (0.0624)</td>
<td>0.0536 (0.0789)</td>
<td>0.515*** (0.178)</td>
<td>0.461 (0.304)</td>
<td>1.269*** (0.475)</td>
<td>0.928*** (0.373)</td>
<td>0.345* (0.289)</td>
<td>1.108*** (0.156)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age over 40</td>
<td>-0.162*** (0.0587)</td>
<td>-0.338*** (0.0568)</td>
<td>-0.0231 (0.0690)</td>
<td>-0.490*** (0.169)</td>
<td>-0.560*** (0.132)</td>
<td>-0.919*** (0.272)</td>
<td>-0.285*** (0.266)</td>
<td>0.345* (0.312)</td>
<td>-0.680*** (0.215)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Public sector</td>
<td>0.782*** (0.0756)</td>
<td>0.568*** (0.0925)</td>
<td>0.851*** (0.0946)</td>
<td>0.901*** (0.168)</td>
<td>0.577*** (0.180)</td>
<td>1.246*** (0.426)</td>
<td>1.269*** (0.419)</td>
<td>0.345* (0.353)</td>
<td>0.911*** (0.217)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Oil sector</td>
<td>2.738*** (0.0932)</td>
<td>3.266*** (0.100)</td>
<td>2.584*** (0.105)</td>
<td>3.057*** (0.122)</td>
<td>3.217*** (0.274)</td>
<td>2.857*** (0.285)</td>
<td>3.974*** (0.375)</td>
<td>3.104*** (0.414)</td>
<td>2.193*** (0.457)</td>
<td>3.430*** (0.760)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing</td>
<td>2.496*** (0.0518)</td>
<td>2.596*** (0.0480)</td>
<td>2.413*** (0.0624)</td>
<td>2.751*** (0.135)</td>
<td>2.861*** (0.107)</td>
<td>2.405*** (0.263)</td>
<td>2.615*** (0.250)</td>
<td>2.257*** (0.252)</td>
<td>3.129*** (0.209)</td>
<td>2.299*** (0.123)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age over 40 with post-B training</td>
<td>-0.0476 (0.0931)</td>
<td>0.00479 (0.0865)</td>
<td>-0.117 (0.108)</td>
<td>0.647** (0.320)</td>
<td>0.0976 (0.208)</td>
<td>0.639 (0.544)</td>
<td>-0.198 (0.616)</td>
<td>0.0237 (0.568)</td>
<td>0.546 (0.396)</td>
<td>0.184 (0.230)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age over 40, work for public sector</td>
<td>-0.137 (0.108)</td>
<td>-0.238*** (0.120)</td>
<td>-0.0499 (0.132)</td>
<td>-0.310 (0.174)</td>
<td>-0.772*** (0.299)</td>
<td>-1.062 (0.263)</td>
<td>-0.230 (0.684)</td>
<td>1.143* (0.581)</td>
<td>0.0958 (0.613)</td>
<td>-0.157 (0.459)</td>
<td>0.0958 (0.291)</td>
<td></td>
</tr>
<tr>
<td>Noncitizen</td>
<td>0.363*** (0.0767)</td>
<td>-0.123 (0.200)</td>
<td>0.853*** (0.235)</td>
<td>-1.157*** (0.348)</td>
<td>0.232 (0.359)</td>
<td>0.340*** (0.120)</td>
<td>0.546 (0.160)</td>
<td>0.184 (1.204)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-8.418*** (0.443)</td>
<td>-8.861*** (0.482)</td>
<td>-6.613*** (0.597)</td>
<td>-6.687*** (0.723)</td>
<td>-7.275*** (1.000)</td>
<td>-15.28*** (0.989)</td>
<td>-10.30*** (1.864)</td>
<td>-8.127*** (2.070)</td>
<td>-10.01*** (1.408)</td>
<td>-6.997*** (1.334)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Authors’ computations from IPUMS-CPS March Supplement, 1968–2012. Robust standard errors in parentheses, ***p < 0.01, **p < 0.05, *p < 0.1.
independent variable. Because the changes are expressed as percentages and not in units that differ across independent variables, elasticities are a useful way to compare the impacts of different variables in the same equation.

Table 6 provides the elasticities on the two key variables: post-baccalaureate degrees and expected wage and salary incomes. For all groups the elasticities of expected wages exceed the elasticities for post-baccalaureate work. For white males, the degree effect exceeds the wage effect in 1968–1989. In the 1990–2012 periods, the two effects are about the same for white males. For white females and Asians the degree effect dominates the wage effect. But for blacks and Hispanics the wage effect exceeds the degree effect.

The results displayed in Table 6 refer to the impacts of post-baccalaureate education versus expected wages on the probability of being a chemist across years and subgroups. To interpret these results in terms of representation ratios, we adopt a clever rule: the elasticity of the representation ratio for group \( k \) with respect to variable \( x \) equals the difference in the elasticities of the probabilities for the \( k \)th group versus all groups. In essence, if order for a factor \( x \) to increase the representation \( R \) for the \( k \)th group, the elasticity of the probability \( P(k) \) must be larger than the elasticity of the probability \( P \), or, the effect on the subgroup has to be larger than the effect for all groups together.

Table 7 reports the elasticities of \( R \) with respect to post-baccalaureate education and for expected wages for each group. The entries in the table are the differences between the \( k \)th group’s

---

*The advantage of computing the elasticity of the representation ratio is that it depends on the difference between the elasticities of the probabilities for the \( k \)th group and all groups.
elasticities and the overall elasticities reported in Table 6. The values displayed in bold letters are positive, meaning that a factor increases the representation of a given group in the chemistry profession. There is support for the pipeline model in the case of white males and for Asians. Increases in the receipt of post-baccalaureate education within these groups results in an increase in these groups’ representation in the profession. The impacts of increases in post-baccalaureate education for blacks, white women, and Hispanics do not increase their representation in the profession, holding constant all other factors. Thus, ironically, efforts to increase the supply of women and underrepresented minorities do not uniformly increase their representation in the profession.

Table 7 reveals that demand-side factors influence the representation of blacks and Hispanics in the chemistry profession. The elasticity of the probability of employment in the chemistry professions with respect to expected wages is larger for blacks and Hispanics than it is for all groups. The result is that the representation ratios for blacks and Hispanics increase when expected wages are higher.

These findings call into question one of the tenants of the pipeline model. The pipeline explanation for the underrepresentation of women and minorities in STEM fields suggests that shortages from these groups arise from insufficient numbers of persons with requisite skills or advanced training. Increases in advanced training, then, ought to increase the representation of underrepresented groups. This is clearly a supply-side characterization of the market for STEM workers. These findings suggest that such supply-side factors do not always operate as intended across all demographic groups.

**TABLE 6: Elasticities of the probability of being employed as a chemist with respect to expected wages versus post-baccalaureate degrees**

<table>
<thead>
<tr>
<th></th>
<th>Expected wage</th>
<th>Post-B degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>0.219***</td>
<td>0.232***</td>
</tr>
<tr>
<td></td>
<td>(0.0445)</td>
<td>(0.0477)</td>
</tr>
<tr>
<td>White males</td>
<td>0.0531</td>
<td>0.215***</td>
</tr>
<tr>
<td></td>
<td>(0.0592)</td>
<td>(0.0705)</td>
</tr>
<tr>
<td>White females</td>
<td>-0.00912</td>
<td>0.0454</td>
</tr>
<tr>
<td></td>
<td>(0.104)</td>
<td>(0.0995)</td>
</tr>
<tr>
<td>Hispanics</td>
<td>0.922***</td>
<td>0.344*</td>
</tr>
<tr>
<td></td>
<td>(0.189)</td>
<td>(0.209)</td>
</tr>
<tr>
<td>Blacks</td>
<td>0.195</td>
<td>0.329**</td>
</tr>
<tr>
<td></td>
<td>(0.145)</td>
<td>(0.132)</td>
</tr>
<tr>
<td>Asians</td>
<td>0.0794</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.158)</td>
<td></td>
</tr>
</tbody>
</table>

Source: Authors’ computations from IPUMS-CPS March Supplement, 1968–2012

Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
8. SUMMARY AND CONCLUSIONS

We have used the case of changes in diversity in the chemistry profession to illustrate two key points: (1) not all women or minority group members realize uniform improvements in their relative representation within the profession as the profession becomes more diverse; and (2) pipeline explanations provide only weak explanations for these changes in representation. The conventional approach to understanding the underrepresentation of women and minorities in STEM fields is typically characterized by a pipeline model. Pipeline models suggest a linear progression from high school science and math preparation to a four-year college and university enrollment and STEM majors to the STEM workforce. The explanation for the underrepresentation of women and minorities in the STEM workforce in these models is that women and minorities are underrepresented at different critical transition points from high school to college to graduate school to the workforce. The most salient transition point is often viewed as post-baccalaureate education. In the pipeline model, increases in the supply of persons with graduate degrees in STEM fields ought to increase elastically the number of persons employed in the field. Our findings do not support this view of the world.

An alternative model suggests that women and minorities often come about their interest, and therefore opportunities to pursue STEM careers, through a circular path, often outside the normal pipeline and disproportionately through paths that are typically not associated with matriculation in major graduate research institutions, such as attending minority serving institutions (MSIs) and two-year or community colleges. This alternative model—the pathways model—posits that there are multiple routes toward the required training for science careers and that the underlying problem is not the undersupply of graduates in science but barriers that undervalue these alternative routes taken by women and minorities.

The conventional pipeline model of entry into STEM careers suggests that there are multiple transitions along this pipeline from high school, to college, and then to the STEM workforce.

<table>
<thead>
<tr>
<th>TABLE 7: Representation ratio elasticities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elasticity of representation ratio with respect to expected wages</td>
</tr>
<tr>
<td>White males</td>
</tr>
<tr>
<td>White females</td>
</tr>
<tr>
<td>Hispanics</td>
</tr>
<tr>
<td>Blacks</td>
</tr>
<tr>
<td>Asians</td>
</tr>
</tbody>
</table>

Source: Authors’ computations from IPUMS-CPS March Supplement, 1968–2012
The first transition, from high school to a science major in a four-year public or private college or university, requires as a prerequisite college preparatory-level mathematics and science courses. There is an array of opportunities and choices that predict matriculation and graduation as a science major.

Although there may be a primary pipeline for majority group members toward STEM careers, minorities and women may reach the field through alternative pathways. One of the critical issues is whether the absence of advanced mathematics and science classes in some high schools heavily represented by racial minority group members means that remedial pathways must be undertaken if one is interested in pursuing a STEM career. Community colleges, for example, often are seen by some minorities as the alternative pathway toward four-year colleges and universities. Historically black colleges and universities, tribal colleges, and Hispanic servicing institutions are notable because they offer an alternative pathway to STEM careers.

Elsewhere, we have explored the impacts of pathways versus pipelines in assessing diversity in the medical profession (Myers and Fealing, 2012). Like chemistry, the medical sciences have become more diverse. And, like chemistry, improvements have not been uniform across all racial/ethnic and gender groups.

Future research might formally model pathways to other STEM careers and undertake the appropriate tests to determine whether the existing pool of minority STEM workers follows a conventional pipeline or alternative pathways to the profession. Such a test would be valuable to policy makers who heretofore have accepted without contest the notion that the most efficient investment of public funds toward remedying the problem of underrepresentation in STEM is by moving more women and minorities through the pipeline.

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