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CLOSING THE INNOVATION GAP IN PINK AND BLACK

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ABSTRACT

Recent research shows the negative impact of discrimination not only on the targets of discrimination but also on the economy as a whole. Racial and gender inequality can limit the entire economy's productive capacity and innovation outcomes. Using new data from NSF's Survey of Earned Doctorates on the scientific workforce from 1980 to 2019, as well as patenting and commercialization data, we examine racial and gender disparities at each stage of the innovation process—education and training, the practice of invention, and commercialization. While improving along certain dimensions over time, we find persistent racial and gender disparities consistent with the current literature. To reverse the negative effects on productive capacity and long-run economic growth, we also discuss the literature on mitigating discriminatory practices at each juncture, which could have significant distributional effects as access to good jobs expands.

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1 Introduction

The role of innovation in driving economic growth is nowhere more central than in endogenous growth theory, which posits that increasing the arrival rate of ideas is essential to increasing economic growth (Romer, 1990).[1] However, a growing body of evidence shows that discrimination, especially systemic racism and sexism, hinders innovation at every stage of the process, from education and training, to the practice of invention, to the commercialization of those inventions (Cook and Kongcharoen 2011, Cook 2014, Cook 2019). In principle, this discrimination not only diminishes outcomes for African Americans and women but affects the rate and direction of innovation for the economy as a whole. In a study of PhDs, Cook and Yang (2018) estimate that GDP per capita could be 0.6 to 4.4 percent higher if women and African Americans were able to participate more fully in the innovation economy. Similarly, Hsieh et al. (2019) estimate a reduction in productivity of 20 to 40 percent over the last 50 years as a result of the misallocation of talent due to discrimination, and Peterson and Mann (2020) estimate the cost of systemic racism to be $16 trillion and over 6 million jobs over the last 20 years. In sum, there is a growing body of evidence that racism has limited our productive capacity.

In light of this scholarship, we examine discriminatory behavior and outcomes at each stage of the innovation process – education and training, the practice of invention, and commercialization of invention. We also discuss the literature on ways to mitigate discrimination and increase inclusiveness, which could have significant distributional effects as access to good jobs expands.

In general, jobs in the innovation economy are attractive relative to jobs in the broader economy. In 2017, the unemployment rate for scientists and engineers was 2.7 percent compared to 3.1 percent for college graduates and 4.9 percent for the US overall, and included 7 to 25 million workers in jobs related to the innovation process (NSF, 2020). These innovation-related jobs have grown 3 percent annually from 1960 to 2013 compared with 2 percent for the broader workforce, and have paid substantially more, with a median income in 2017 of $85,390 compared to $37,690 for all workers (NSF, 2020).

Several datasets undergird the study of the innovation economy.[2] The National Science Foundation (NSF) collects data on the science and engineering (S&E) workforce, which it defines as workers in S&E occupations, workers holding S&E degrees, and workers who use technical expertise on the job. NSF surveys S&E students, graduates, and workers, including its Survey of Earned Doctorates and the National Center for Education Statistics Integrated Postsecondary Education Data System Completions Survey. In addition to NSF survey data,

[1] The paper draws heavily on Cook (2019), Cook (2020a), and Cook (2020b).

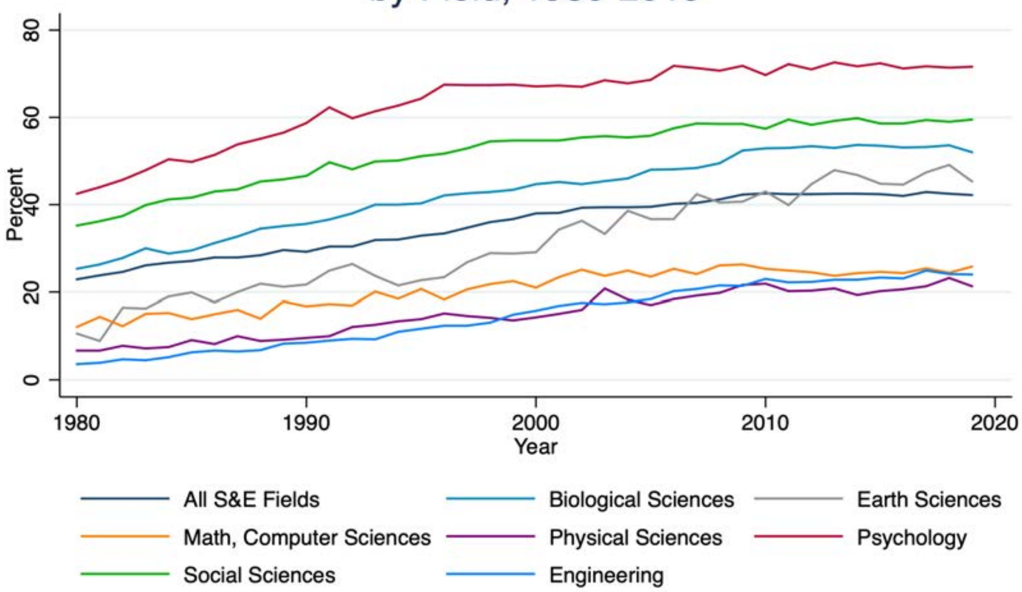
[2] For the purposes of this paper, the terms "innovation economy," "innovation sector," "science and engineering (S&E) economy," and "S&E workforce" are used interchangeably, as are the terms "innovation jobs" and "S&E occupations".

patenting and commercialization data are available from the USPTO. Race, ethnicity, and gender are not recorded in patent data, but a plethora of methods to identify inventor race and gender have been successfully applied (Cook, 2014; Cook and Kongcharoen, 2011).

2 Phase I: Education and Training

Women and African Americans have increasingly succeeded in accessing the first phase of the innovative process: getting doctorates in the sciences and performing basic research that undergirds the stock, flow, and direction of knowledge. In 1970, only 9 percent of all doctorates in S&E fields were awarded to women; by 2018, that share was nearly 47 percent. In 1970, only 1 percent of all S&E doctorates went to African Americans; by 2019, that share was roughly 5.5 percent. For context, African Americans represent just over 13 percent of the population (U.S. Census, 2019). Figures 1 and 2 show these data for 1980 to 2019[3].

Figure 1. Share of S&E Doctorates Received by Women by Field, 1980-2019

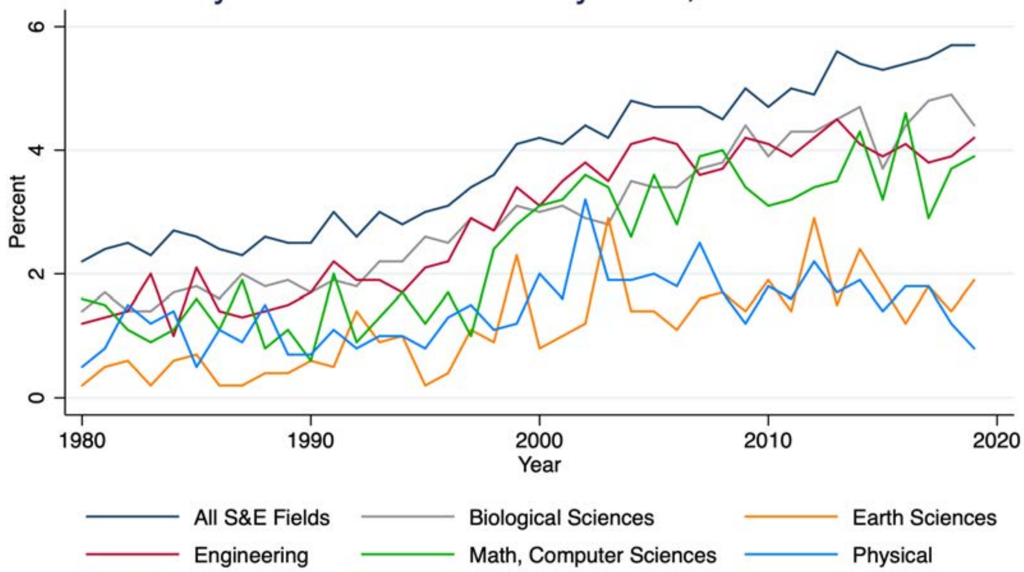


Note: Earth Sciences include Atmospheric and Ocean Sciences; Biological Sciences include Agricultural Sciences.
Source: NSF NCSES, Survey of Earned Doctorates

However, despite gains, a divide remains for both groups. Examples of persistent barriers to women and African Americans pursuing degrees in science, technology, engineering and math (STEM) fields abound. Jennifer Selvidge, a former honors student in materials engineering at

[3]NSF (2001), NSF (2021). The trends are similar for master's and bachelor's degrees and are comparable through 2018. This is significant because most commercialized inventions originate from those with bachelor's degrees and master's degrees.

Figure 2. Share of S&E Doctorates Received by African Americans by Field, 1980-2019



Note: Earth Sciences include Atmospheric and Ocean Sciences; Biological Sciences include Agricultural Sciences.
Data only include US citizens and permanent residents.
Source: NSF NCSES, Survey of Earned Doctorates

the Massachusetts Institute of Technology, related experiences she had as an undergraduate that are common to many women and African Americans. She reported being told "hundreds of times" that, as a woman, she did not deserve to be there and that metallurgy was a "man's field," (Selvidge, 2014). She also witnessed sexual harassment by teaching assistants and male professors attempting to publicly humiliate the vastly outnumbered female faculty. In addition to observing people of color being actively advised to change majors and leave the department, she was also subject to a teaching assistant who claimed that "black Americans are genetically inferior due to slavery era breeding practices," (Selvidge, 2014).

Interventions: Mentoring and Exposure

Targeted mentoring programs have been shown to have significant and long-lasting effects on inclusion in STEM careers, where income, race, and gender gaps in acquiring education have been due to a lack of mentoring and exposure to science and innovation careers rather than differences in ability. Initiatives to increase the number and share of women and under-represented minorities in STEM majors and fields can be effective (Haseltine and Chodos, 2017). Mentoring programs can supply the essential exposure needed to expand participation. Oliver et al. (2021) study a specific example of this exposure effect, showing that minority teaching assistants in chemistry lab significantly improve minority student retention and performance.

The American Economic Association (AEA) launched a summer boot camp in the 1970s to increase racial and ethnic diversity in the economics profession. Students attend courses taught by faculty from a broad range of racial and other demographic backgrounds, and mentoring is a key component of the program. Becker, Rouse, and Chen (2016) estimate that program participants were over 40 percentage points more likely to apply to and attend a PhD program in economics, 26 percentage points more likely to complete a PhD, and about 15 percentage points more likely to work in an economics-related academic job. All told, the AEA summer program may directly account for 17 to 21 percent of the PhDs awarded to minorities in economics over the past 20 years.

The Makers + Mentors Network (formerly US2020) connects underserved and underrepresented youth with local STEM professionals in mentorship programs. Makers + Mentors Network operates in 21 communities across the country, serving over 150,000 students and 20,000 mentors annually, with a goal of engaging 1 million STEM professionals as mentors for students in kindergarten through graduate school (see makersandmentors.org). The program also places AmeriCorps VISTA members in its community efforts, and a planned Maker Fellows program partners with community colleges and historically black colleges and universities. Hands-on learning experiences, and after-school and summer programs strengthen students' foundation for learning at key moments in their education and career.

Finally, young children can also benefit from exposure to invention and innovation. Recent empirical support for the role of early exposure in creating more inventors can be found in a study of the inventor life cycle (Bell, Chetty, Jaravel, Petkova, and Van Reenan, 2019). High school programs, such as the InventTeams program at the Lemelson-MIT is found to have a positive impact (Couch, Estabrooks, and Skukauskaite, 2018). Spark Lab at the Lemelson Center for the Study of Invention and Innovation at the Smithsonian Institution and at a handful of affiliate museums is an example of a successful early education program. The activity space allows children to create an invention and to help them think about making the invention useful. To be sure, in the face of systemic racism, sexism, and other forms of discrimination, interventions promoting mentoring and exposure may be insufficient to augment the participation of women and underrepresented minorities. We discuss this further below.

3 Phase II: The Practice of Invention

The second stage of the innovation process is the practice of invention, e.g., in corporate or academic laboratories. Here, women and African Americans have also faced pervasive barriers. For example, throughout history women and African Americans have had to battle the perception that they were mentally inferior and technically incompetent and were not welcome in the white, male culture of corporate research and development (R&D) labs.

They were also barred from participating or limited in their participation in scientific fairs and barred from joining professional scientific and engineering societies until the mid-20th century, thus depriving them of the social capital and connections required to advance their careers and develop their inventions (Cook 2011; Oldenziel 1999; Sinclair 2004). Patent data can provide crucial measures and indicators of discriminatory access.

A Access to patenting

Legal access to the U.S. patent system offered opportunities, albeit limited, for women and African Americans. There was no language in the original Patent Act of 1790 limiting patentees based on gender, race, age, or religion. Therefore, decades before emancipation and universal suffrage, women and (free) African Americans could, and did, invent and earn U.S. patents[4]. Still, women and African Americans did not have equal protection under patent laws. While free African Americans were allowed to obtain patents, the U.S. Patent and Trademark Office (USPTO) refused to grant patents to enslaved African Americans. Moreover, laws in many states assigned all marital property rights to husbands, and thus prohibiting married women from owning or controlling patents in their own names. These draconian social norms and policies deterred many women and African Americans from ever becoming inventors [5].

Even without discriminatory laws, discriminatory practice leads to inequality in patenting outcomes to this day. Jensen, Kovács, & Sorenson (2018) find that, all else being equal, patent applications with female lead inventors are rejected more often than those with male lead inventors. Addressing this unequal gender-based access to patenting is important, because patents are an input to commercialization, as discussed below. The 2018 SUCCESS Act—and companion IDEA Act currently being considered—are a response to research on diversity in innovation (especially Cook and Kongchareon, 2010) and seek to collect demographic data on patent applicants in order to increase participation by underrepresented groups.

Patent enforcement is also a factor in the differential ability of women and minorities to profit from the fruits of their invention. Lonnie Johnson, inventor of the Super SoakerTM water gun who is African American, had to doggedly pursue Hasbro to receive the $72.9 million owed to him for his patented and trademarked invention. While his lawsuit was ultimately successful, most African American firms are small and do not have the legal and

[4]For example, in 1809 inventor Mary Kies was the first woman to receive a U.S. patent, for an improved method of weaving straw with silk thread to make hats. Similarly, Thomas L. Jennings was the first free person of color to receive a U.S. patent in 1821, for a dry-cleaning process. On Kies, see USPTO (1888). On Jennings, see Sluby (2005). On the egalitarian nature of the U.S. patent system, see Khan (2005).

[5]On discriminatory patent laws and policies, see Gage (1883), Baker (1902), Pursell (1981), Lubar (1991), and Sluby (2004).

financial resources to aggressively protect their intellectual property[6]. This is in addition to a substantial literature on gender and racial pay gaps.

Patent data, however imperfect, provide a measure of inventive activity and of unequal access for women and African Americans[7]. USPTO data from 1970 to 2006 show patent output of 235 patents per million for all U.S. inventors; for women, the number is 40 patents per million and for African Americans, it is 6 patents per million (Cook 2007, 2014; Cook and Kongchareon 2010). These figures understate the effect of unequal representation because patent teams comprising men and women generate higher-value patents than single-sex teams (Cook and Kongchareon 2010). The misallocation of resources suggested by these findings could lead to suboptimal levels and rates of innovation and economic growth, which are exacerbated by inter-generational effects of inventorship. Bell, Chetty, Jaravel, Petkova, and Van Reenen (2019) find that children from high-income families who grow up around other inventors are more likely to patent, while children from low-income families with limited exposure to emerging technology are less likely to patent.

B Access to resources

Patent data provide clues to some of the mechanisms behind the underrepresentation of women and African Americans in invention, especially access to workplaces that provide the necessary resources for invention and innovation. Employees who produce inventions on the job are contractually obligated to assign their patents to their employers (usually for $1) once they are issued by the patent office (Fisk, 2009; Mirowski, 2011). Thus, a patent assignment typically implies an employee invention with commercial value, and gender and race gaps can be measured in patent assignments, as well. The likelihood of female inventors assigning a patent was 51 percent lower than male inventors and African American inventors were 46 percent less likely than other U.S. inventors to assign a patent (Cook and Kongchareon 2010).[8]

In addition, private firms are better at commercializing inventions than government employers, where African American scientists and engineers are concentrated. Commercialization is more difficult in the government sector because of historical practices prior to the Govern-

[6]See *Black Enterprise*'s list of top 100 African American firms, which reports their size (Black Enterprise 2019).

[7]For a variety of reasons, patent data are an imperfect proxy for measuring inventive activity. First, not all inventions are legally protected. Second, the mechanisms for legal protection vary widely, including patents, copyrights, trademarks, trade secrets, or some combination thereof. Finally, many patents are not economically viable. These include vanity patents, defensive patents (patents obtained but purposefully not developed to prevent a competitor from inventing in a complementary area), and inventions whose commercialization may be cost-prohibitive. On the methodological possibilities and limitations of using patent data, see Schmookler (1966), Griliches (1990), and Jaffe and Trajtenberg (2002).

[8]Odds are calculated relative to assignment to an individual.

ment Patent Policy Act (Bayh-Dole Act), which encourages the development of government patents. These practices include strict ethics policies and risk aversion among government laboratory employees and contractors, especially with respect to entrepreneurship, production, and ownership.[9] But even among government employees who invent, African Americans are less likely to move to a corporation than their white co-inventors (Cook 2003).

NSF data on employment provide more direct evidence that women and African Americans have unequal access to corporate employment and invention resources. The share of women working in an S&E field rose from 31 percent to 37 percent between 1993 and 2010. Over the same period, women in S&E occupations rose from 23 to 28 percent (NSF 2014). By 2019 women made up 29 percent of the S&E workers, and the percentage of African Americans working in S&E had increased to 5 percent (NSF 2021). But both female and African American scientists and engineers are more likely to work in non-S&E occupations than in S&E occupations.

Figures 3a and 3b report selected occupations for women and African Americans with doctorate degrees. Note that 70 percent of psychologists were women in 2019 but just 14 percent of engineers. In 2010, 25 percent of the workforce in computer and mathematical sciences were women, and in engineering, 13 percent were women; in 2019 these shares were 29 percent and 14 percent, respectively (NSF 2014, 2021).

Examining specific occupations within a field, more than 57 percent of all the people in S&E-related occupations are women, with women making up nearly 70 percent of health-related workers, more than half of S&E precollege teachers, and one fifth of S&E technologists and technicians.[10] Female scientists and engineers constitute over half of scientists and engineers in non-S&E occupations. Women often start their careers working in the innovation economy but then leave for various reasons, including the need to provide child care, the lack of family-leave policies, and poor workplace climate (NSF, 2021; Pepiton, 2011).

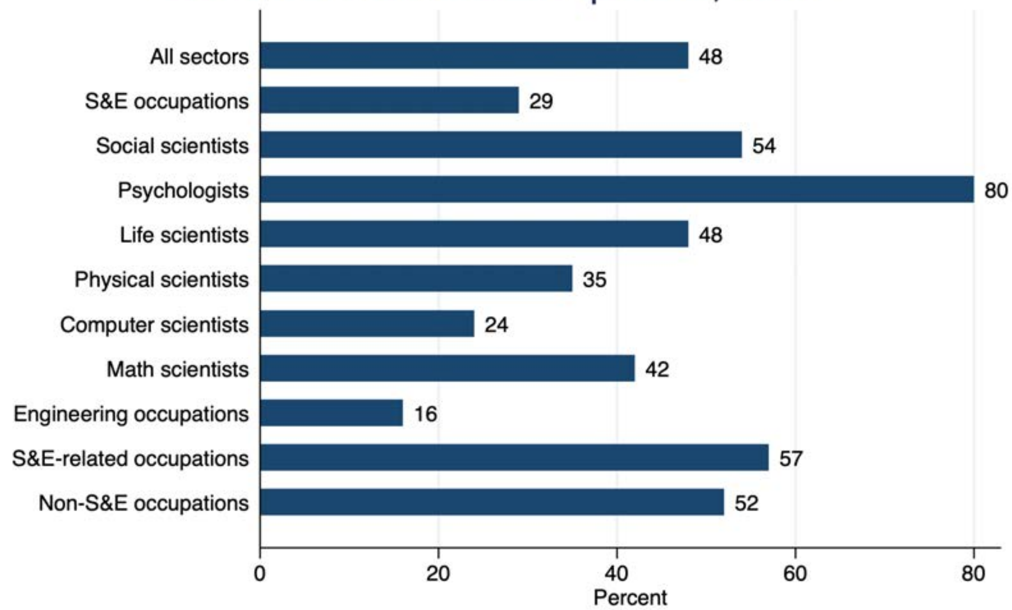
A similar pattern emerges for African American scientists and engineers, who make up just 5 percent of workers employed in S&E occupations. Among S&E occupations, African American scientists and engineers are more concentrated among social and related scientists and computer and math scientists than they are in other S&E occupations. Among S&E-related occupations, African American scientists and engineers, like female scientists and engineers, are more concentrated in health-related occupations and in precollege teaching than in other S&E occupations. More African American scientists and engineers are in non-S&E occupations than are in S&E and S&E related occupations.

While women and African American scientists and engineers are growing as a share of the

[9] Beyond the greater barriers to commercialization in the government sector relative to other sectors, there is also an issue of selection. Government jobs are often more stable relative to the private sector, and government agencies have traditionally been risk averse.

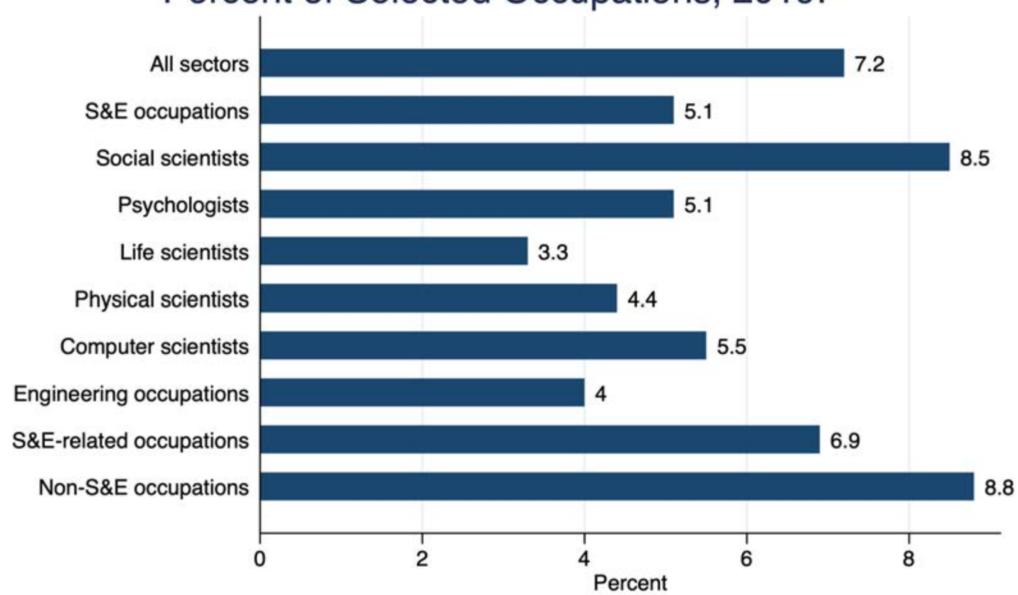
[10] These data refer to all degree-holders – bachelor's, master's, and doctorate.

Figure 3a. Employed Women Scientists and Engineers
Percent of Selected Occupations, 2019.



Source: NSF WMPD 2021

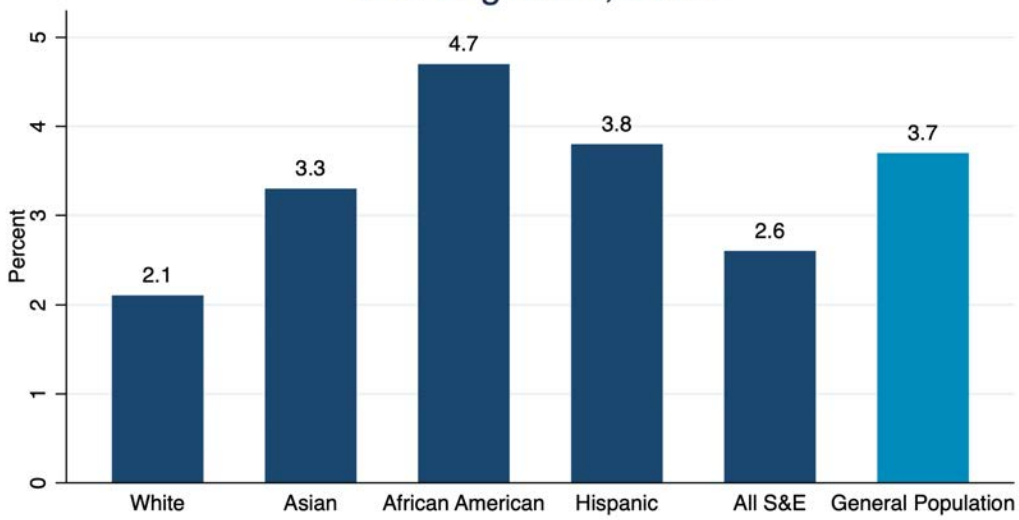
Figure 3b. Employed African American Scientists and Engineers
Percent of Selected Occupations, 2019.



Note: Data was not available for the Math scientists occupation
Source: NSF WMPD 2021

innovation labor force, unemployment rates vary significantly by racial and ethnic group (see Figures 4 and 5). The African American unemployment rate, at just under 4 percent, is higher than for Hispanics, and Asians, and higher than the average for all scientists and engineers.

Figure 4. Unemployment Rates among Scientists and Engineers, 2019.



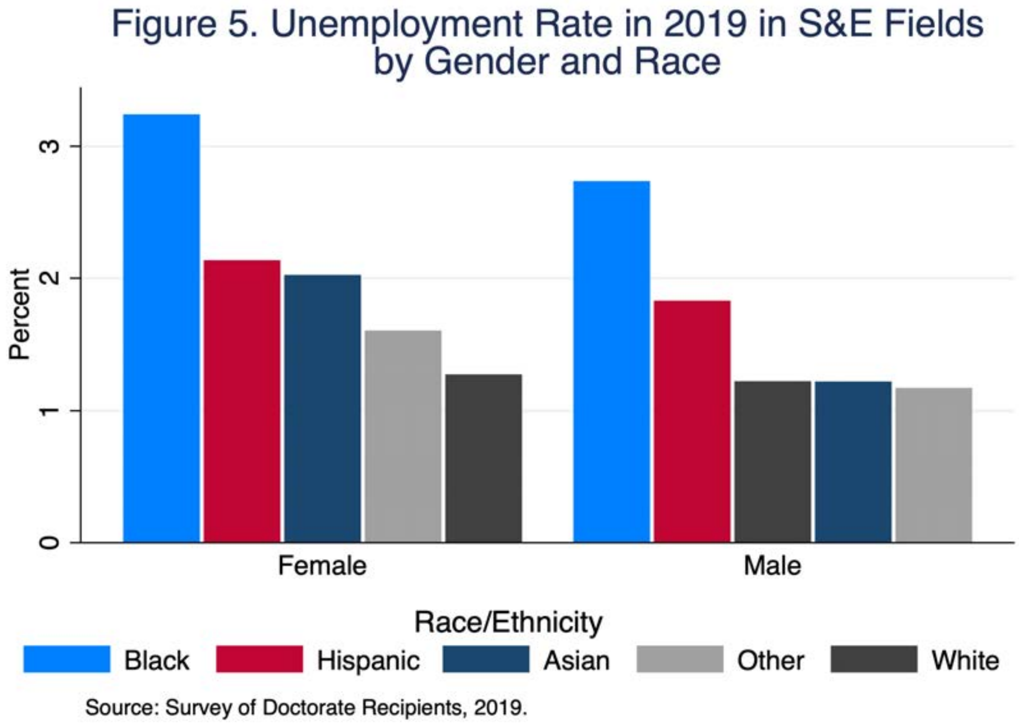
NOTE: Unemployment rate calculated as the percentage of the labor force not working and looking for work. Total U.S. labor force unemployment rate covers the labor force ages 16 and over.
Source: NSF WMPD 2021

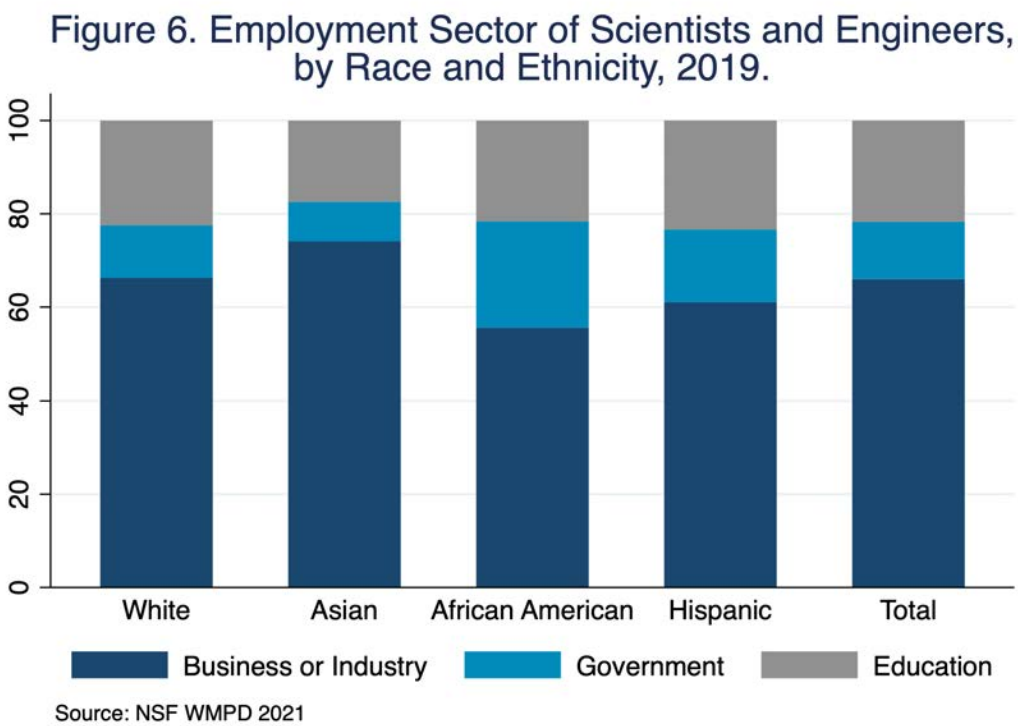
Figure 6 shows where scientists and engineers are employed by sector. Most scientists and engineers are employed in business or industry, but underrepresented minorities are more heavily employed in education and government. This has implications for economic growth because while scientists in government laboratories work hard at patenting, they have binding constraints on their ability to commercialize their inventions relative to their private-sector peers.

Interventions: Workplace Policies

This equilibrium underemployment of women and minorities is crucial to address if efforts to expand their recruitment into education and training succeed. The “Lost Einsteins” (Bell, Chetty, Jaravel, Petkova, and Van Reenen (2019) will be an even greater loss if they have been educated but sidelined, which NSF employment data suggest is currently the case for so many women and minority scientists.

At present, the literature in economics on interventions related to problems of discrimination in the patent office and innovative firms is scant. Instead, data are analyzed to estimate the magnitude of the problem. The patent and employment data discussed above relate to





the extensive margin in innovative activity, i.e., whether women and minorities are able to access the patent office or private employment. However, the weak retention of women and minorities in private firms suggests that the intensive margin may also play a significant role in unequal outcomes—how women and minorities are treated once they are inside private firms can cause them to leave, resulting in an equilibrium with relatively few women and minorities engaging in inventive activity.

Edray Goins's experience is illustrative. Dr. Goins was one of the few African American mathematicians with tenure at a major research university. In 2018, after more than a decade on the faculty of Purdue University, he left, choosing a full professorship at Pomona, a liberal arts college, instead. He explained that this practically unheard of move was due to a feeling of isolation, along with instance after instance of subtle hostilities and unspoken disrespect, such as reports from graduate students that they'd been warned by a white professor not to work with him (Harmon, 2019). Many similar anecdotes from the sciences and beyond were shared on Twitter and other social media platforms under the hashtags #BlackandSTEM, #blackintech, and #BlackInTheIvory, particularly following the murder of George Floyd.

Income data are indicative of unequal treatment within firms. While the median salary for men in the innovation economy in 2010 was $80,000, it was only $53,000 for women, or 66 percent of the median male salary (NSF 2017).[11] In 2019, the median salary for scientists and engineers was $95,000 for men, yet it was only $70,000 for women, or 74 percent of the median male salary (NSF 2021). Some of the gap is attributable to the different occupations people perform across gender, with more men in S&E occupations, which tend to be higher paid. Female scientists and engineers have lower median salaries than men in most S&E occupational groups. Within S&E occupations, the female-to-male median salary narrows to 80 percent and ranges from 67 percent for workers aged 50-75 to 84 percent for workers aged 30 to 39. The female-to-male median salary is 80 percent in S&E-related occupations and 68 percent for non-S&E occupations. "Biological, agricultural, and other life science" is the only occupation in which the median female salary exceeds the male median salary with a female-to-male median salary of 1.05.[12]

The salary gap between African Americans and whites is less than that between men and women. In 2010, the median salary for whites was $72,000, and for African Americans it was $56,000, or 78 percent of the median salary for whites.[13] In 2019, this gap remained largely the same, at 79 percent. For S&E occupations, the gap narrows to 88 percent. However, among S&E occupations, the gap is widest among physical scientists (79 percent). There is practically parity in engineering, with psychologists' and social scientists' median salary for African Americans higher than the median salary for whites, with a ratio of 1.03 and 1.06 respectively.[14]

[11] As is true for any salary data, differences vary across occupations, age groups, race, ethnicity, etc.

[12] NSF (2021); authors' calculations.

[13] Salary data for 2010 are from NSF (2014) and are for full-time workers with the highest degree in an S&E field. Salary data for 2019 are from NSF (2021).

[14] NSF (2021); authors' calculations.

Comparing across women, African American S&E salaries were 87 percent of white women in all occupations, and African American non-S&E salaries were 84 percent of white women in all occupations. However, there is practically salary parity in S&E occupations and in S&E-related occupations. The largest gaps within S&E occupations are among engineering occupations (85 percent), but among social scientists and psychologists, the ratio of the median salary of African American women to white women is 1.24 and 1.12 respectively.[15]

These race and gender wage gaps are concerning in their own right, generating cross-sectional wealth inequities. However, where they may also indicate hostile work environments that lead to equilibrium underrepresentation in private firm employment, long-term distributional consequences may also arise. The earnings gap between workers in the innovation economy and the overall economy is substantial, with workers in the innovation economy earning more than double the average American worker in 2019.[16] Thus, when women and minorities leave private firms, they experience lowers earnings, either working outside the innovation economy or in government and education, where salaries are lower than those in business or industry. This further deepens the income inequality among S&E workers.

4 Phase III: Commercialization of Invention

The third and final stage in the innovation process is the commercialization of invention. Commercialization requires drawing on financial and social capital to introduce the invention into the economy. In addition to the activity of large firms, in which S&E employees invent and commercialize an invention as discussed above, inventors also start their own firms. This latter avenue also presents disproportionate obstacles for women and African Americans.

The gap in the commercialization process was in the public eye in 2012 when Ellen Pao sued her employer, the noted venture capital firm Kleiner Perkins Caufield and Byers, for gender bias in promotion. She argued that her performance, like that of other women and people of color, was negatively affected because the firm's partners did not sponsor her investments or include her in key activities and decisions of the firm. She has also described her experience as CEO of a social media technology company, Reddit, where she faced gender-related harassment and threats of violence (Pao, 2017).

Female and African Americans inventors once intentionally obscured their identities in order to counter discrimination and to profit from their inventions. For example, Garrett Morgan, an African American inventor based in Cleveland at the turn of the 20th century, correctly surmised that white consumers would be skeptical of buying products from an African American inventor. So, Morgan hired white and Native American actors to portray him to sell

[15]NSF (2021); authors' calculations.
[16]NSF (2021), FRED.

his gas mask (Cook 2012). Many of the iconic lamp designs associated with Louis Comfort Tiffany were in fact created by Clara Driscoll and other "Tiffany Girls." Their identities were not revealed in order for the value of the designs to be maximized (Eidelberg, Gray, and Hofer, 2007). Discrimination also forced women and African Americans into bad deals or to forgo commercialization entirely.

Contemporary inventors can generate income from an invention in at least three ways: (1) engage in entrepreneurship and start a new firm (or business unit) to develop, manufacture, and sell the invention; (2) assign (sell) the patented invention for a lump sum; and (3) license the patented invention to another manufacturer, and collect royalties until the patent expires. Data on entrepreneurship, firm ownership, patent assignments, and wealth accumulation from innovative assets suggest that innovation gaps exist and persist for women and African American inventors compared to their white male counterparts.

Start-up data help elucidate how the commercialization of new inventions through entrepreneurship can unlock enormous wealth. Therefore, the differential ability of women and African Americans to accumulate proceeds from innovation and entrepreneurship is striking and helps explain wealth inequality in the United States more broadly. Equity ownership of technology startups is the stage of the innovative process where the largest pecuniary gains are found. Those who own equity stakes, including angel and venture capital investors, founders, employees with stock options, stand to profit greatly from initial public offerings, mergers and acquisitions, stock splits, and other liquidity events.

Details of this process show why unequal access to patenting and resources for invention and commercialization are problematic for economic growth. The practice among venture capital firms of restricting their attention to start-ups with patents pending (Cook and Kongcharoen 2010) exclude women and minorities whose patent applications are disproportionately rejected. And with fewer women and minorities participating in innovative activity, patent quality declines, according to a growing literature on the better outcomes of more-diverse teams (Rock and Grant 2016). When a founding team includes a woman, it outperforms all-male peers by 63 percent, but female CEOs receive only 2.7 percent of all venture funding, and women of color get virtually none: 0.2 percent (Weisul 2016).

In general, it is difficult to find women and African Americans among the ranks of entrepreneurs, top management teams, and boards in the innovation economy. Women and African Americans are often found in legal and marketing departments but are largely missing in technical positions and on boards. In 2014, Fortune ranked several large tech firms based on recently released demographic data. With respect to female executives, Indiegogo was ranked highest, with women constituting 43 percent of leadership roles. Cisco and Pinterest were ranked lowest, with 19 percent women in executive roles. Women constituted just 18.7 percent of directors of boards of S&P 500 firms in 2014, which was up from 16.3 percent in 2011 (Huddleston 2014). In 2015, just 11 percent of venture capitalists were women, and

2 percent were African American (NVCA 2016).

Interventions: Legal and other remedies

What interventions can be undertaken to improve the inclusiveness of commercialization? Legal and policy remedies may offer some mitigation, while practitioners offer suggestions for private ordering solutions.

A Public ordering solutions

Legal remedies are currently being tested in several cases of discriminatory behavior by private firms. The Department of Labor is suing Oracle for $400 million for pay discrimination against women and racial minorities and is continuing to investigate Google's gender gap in salaries. In the spring of 2017, it reported systemic discrimination of women at Google (Lam 2017). Pinterest has similarly been sued for pay discrimination (Schwab 2020). In addition, workers from minoritized groups in the innovation economy have begun to speak more openly about their experiences that identify these firms as allowing or cultivating suboptimal or openly hostile workplaces. A number of these workers have spoken out on social media platforms.

Another approach is legislation, such as California's Women on Boards law, which requires all publicly held corporations whose principal executive offices are located in California to have at least one female director on their boards. In principle, this approach could be extended to include targets for underrepresented racial and ethnic minorities and to apply nationally. Data collection and reporting are another approach to combatting racism and sexism in the workplace generally, which could be particularly appropriate for the innovation economy (Frye 2019). Requiring public reporting of employer pay and promotion data by race and gender would provide greater transparency of employer pay practices (and could include detailed data on domestic and foreign composition). Employers could also be required to report steps taken to address pay and promotion discrimination based on race, gender, ethnicity, and other factors in SEC filings, including eliminating forced arbitration in sexual harassment cases, implementing anti–African American and antisexist bias training for all levels of staff, especially leadership, managers, and supervisors; and increasing funding for enforcement to ensure compliance with equal pay protections and to undertake targeted efforts to examine the prevalence of race and gender bias in pay discrimination cases.

Moreover, measures at federal agencies could also reduce discrimination. The National Academies of Science just completed an extensive review of the premier program within the U.S. government to explicitly promote commercialization of innovation, the SBIR and

STTR programs, which are housed with the SBA (National Academy of Science 2020). While the report focused on the Department of Energy SBIR and STTR programs, the lessons and suggestions directed at the Department of Energy, the SBA, and Congress are largely applicable to any agency. The salient major suggestions relate to diversifying the applicant pool by expanding reviewer pools, optimizing matches between applicants and R&D partners, and implementing virtual mentoring programs to connect SBIR/STTR applicants to national labs. Suggestions from the report would be pertinent for the recruitment, application, and review processes.

The report suggests that the lack of diversity of the applicant pool for flagship innovation programs is partly explained by the lack of diversity among the people who review applications for the programs. Currently the people who serve as reviewers of applications for premier innovation programs are primarily white men, selected for their demonstrated expertise as leaders, research managers, and technical managers at national labs or research universities—positions in which women and minorities are woefully underrepresented. In engineering departments, for example, only 16 percent of professors are women, 2.3 percent are African American, and 3.6 percent are Hispanic. A more-diverse reviewer pool might help to identify more diverse and more innovative projects. To minimize the service burden that underrepresented minorities would have to bear as reviewers, agencies, departments, and national labs should provide incentives in the form of compensation, promotion credits, etc., in the same way that this has been executed at the National Institutes of Health.

The report also speculated that potential female and under-represented minority applicants might lack information about prospective R&D partners. Women and underrepresented minorities are less likely to be in the same professional networks as their white male counterparts and so lack information and connections to research partners that are critical for successful applications. Making this information more publicly available could disproportionately help women and minorities. For example, data on research partners for previous awards in a public and searchable database could be particularly helpful to applicants outside these networks. This would be a low-cost NS that government agencies could undertake that could have substantial impact.

Finally, the report suggested that proximity to national labs that provide R&D expertise confers an advantage on applicants. As a result, potential applicants from underrepresented regions with little or no access to the connections and mentoring essential to find suitable R&D partners are disadvantaged. These geographic distances can be a substantial barrier. The report suggests virtual mentoring programs for women and underrepresented minorities to connect applicants with national labs, thus reducing the barrier caused by geographic distances. A model for this program would be the longstanding Mentor-Protégé Program, which fosters long-term business relationships between small disadvantaged firms and prime contractors. The SBA, as well as various agencies, have this program. In addition, presentations, fairs, and other gatherings to promote the SBIR/STTR program could be extended to locations where there are already inventors from underrepresented minority groups, such as Atlanta and Austin.

B Private ordering solutions

In 2014, less than 7 percent of U.S. venture capital investment was in businesses founded by women, and mere 0.2 percent was in businesses founded by African American women (National Venture Capital Association [NVCA] 2016), even though start-ups with diverse executive teams yield a return two times greater than entirely white teams. A CNBC report faults racial bias of nondiverse venture capital investors. Recent Bloomberg interviews with African American CEOs in Silicon Valley revealed a routine assumption that they were not in charge of their companies: there were constant challenges to their credentials, subtle and overt discrimination, and the regular suggestion that they hire a white business partner to put investors at ease (Anand and McBride 2020). African Americans also lack mentors and social networks, weakening the pipeline of potential entrepreneurs, executives, board members, and funders.[17]

Freada Kapor Klein, a venture capitalist and long-time advocate for diversity in technology companies, points out that while many technology companies claim they are addressing a lack of diversity in their workforce, they can do more (Harrison 2019). Among her suggestions are continued investment in diversity in hiring at all levels, retention initiatives, and making sure all employees value and prioritize a workforce that is diverse and inclusive. Recognizing unequal outcomes is the first step. Policies and business plans that address these inequalities are essential for shared prosperity.[18] And shareholders and investors will need to set specific diversity targets and hold management accountable for those targets.

Separately, CNBC pledged to do its part with access to information, highlighting founders, innovators, and investors who help the business world move toward a more-diverse and more-inclusive future. Information is the key behind increasing firm collection of data on the gender, racial, and ethnic composition of their work force and sharing it with policymakers and researchers.

[17] Sanders and Ashcraft in Wisnioski, Hintz, and Stettler Kleine (2019) includes a rich discussion of gender and implicit bias.

[18] A more comprehensive strategy to address shortcomings related to diversity and inclusion in the tech sector appear in the Klein et al. (2018).

5 Discussion and Final Thoughts

Innovation is an essential input to economic growth. The innovation process begins with education, which macroeconomists have studied as human capital formation, but must be followed by two additional steps, invention and commercialization. By placing existing scholarship on education into the wider context of innovation, bottlenecks in the process can be identified. For example, the impact of policies that create more Einsteins, such as those suggested by van Reenen (2021), may be inefficiently limited by discrimination, which sidelines these new Einsteins.

This sidelining moves distributional issues to the foreground. Whereas distribution and efficiency are typically regarded as separate policy goals, in the innovation setting, unequal access to opportunity creates inefficiencies in the quality, quantity, and direction of innovation. The institutional details and mechanisms of discrimination, which normally elude mainstream economic scholarship, are on full display in the innovation process. Discrimination within the patent office, wage gaps, the low rates of minority female S&E PhDs in S&E jobs all demand greater scrutiny and investigation. Economists must work across disciplines, including institutional and business economists as well as related disciplines outside economics, if a more complete picture is to be obtained.

As a policy goal, distribution has grown increasingly salient. Income-tax data show that income inequality is higher now than in the Gilded Age and has grown recently: from 1993 to 2011, real income grew 10 times more for the top 1 percent than for the bottom 99 percent—57.5 percent compared to 5.8 percent (Saez 2013). This inequality has led to profound political polarization and social unrest and led to greater attention to distribution as a policy goal. The innovation sector raises fundamental questions related to inequality, with its relatively high incomes, considerable wealth, and substantial and growing political influence. If women and African Americans are disproportionately excluded from the sector, even when they have the skills demanded of skill-biased technological change, they will be unfairly and inefficiently deprived of their share of opportunity, wealth, and influence. Indeed, innovation inequality—and the resulting income and wealth inequality—fly in the face of the American ideals of equal opportunity, shared responsibility to achieve shared prosperity, and more and better technological advances to raise living standards for all.

In short, addressing innovation inequality is likely to require solutions that are not just efficient but also just, such as policies that promote equal access and investment in human capital and that challenge the racism and sexism that are now rampant in the technology sector. Economics can play a critical role by moving beyond the narrow analysis of the efficiency cost of discrimination, and engaging with the design of systemic solutions. The faulty rhetoric of sexism is exemplified by a Google engineer, James Damore, who wrote a memo that leaked and went viral in the summer and fall of 2017. This memo, directed at diversity initiatives at Google, argued that women were underrepresented in technology careers because of "inherent psychological differences" between the genders (Cernovich 2017). In fact, women's contributions follow a pattern consistent with economic theories of discrimination, in which women and minorities must clear a higher bar in order to participate. One consequence of discrimination is that their contributions are higher than average quality. For example, Grace Hopper was a pioneer of computing who invented the COBOL language. And African American women, mathematicians Mary Jackson, Katherine Johnson, and Dorothy Vaughn, made key contributions to human space flight at NASA. Featured in the book and film Hidden Figures, these female and minority scientists would otherwise have gone unacknowledged. Google dismissed Damore for "perpetuating gender stereotypes" (Bergen and Huet 2017). A few weeks later a former Google software engineer, Kelly Ellis, and two other women sued Google, alleging discrimination in both the pay and promotion of women. Addressing these inequalities in a systemic way will be central to closing the innovation gap.

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