# 12 The Innovation Gap in Pink and Black

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From a number of perspectives, innovation is a good thing for the economy.[1] Economists have long recognized how the generation and implementation of ideas drives economic growth.[2] Historians also have demonstrated the positive relationship between the commercialization of invention, industrialization, and economic activity in studies documenting early American inventor-entrepreneurs and the creation of the patent system.[3] Statisticians provide further evidence of the innovation economy's importance to the nation; for example, from 1960 to 2013, the number of workers in innovation jobs grew 3 percent annually, compared to 2 percent for the broader workforce.[4]

The benefits of the innovation economy, however, have not been evenly distributed. Despite numerous initiatives to train and cultivate innovators, women and African Americans continue to participate at each stage of the innovation process—from education to patent activity to start-ups—at lower rates than their male and white counterparts. As a consequence, women and African Americans have not enjoyed their proportionate share of innovation's benefits.[5]

For women and African Americans throughout the history of the United States, this pathway to success has been curtailed because of entrenched gender discrimination and racial segregation. Women and African Americans have had less than equal access to education, especially advanced technical training. Discriminatory laws and policies once forbade enslaved blacks from earning patents and married women from owning them. Meanwhile, women and African Americans were for decades systematically excluded from the professional scientific and engineering societies. Likewise, women and African Americans had limited access to wealthy backers and mainstream banks and so were forced to develop different sources for the start-up capital necessary for commercializing their inventions.[6]

Despite major gains since the 1970s, women and African Americans remain underrepresented in the innovation economy.[7] Empirical evidence gathered over decades reveals an even more pervasive underrepresentation. Women and African Americans earn fewer advanced degrees in the STEM disciplines (science, technology, engineering, and mathematics) than the population figures would suggest. Likewise, women and African Americans earn fewer US patents than would be expected and are less likely to commercialize them.

This *innovation gap* represents a lost opportunity, a discriminatory drag on our economy, and further structural evidence of the wide income and wealth gaps in the United States. More seriously, the underrepresentation of women and African American innovators is a failure to deliver on the American ideals of equality and equal opportunity for all. In this chapter, I draw on observations from educational surveys, employment and income figures, and US patent data to describe inequalities at all stages of innovation. I will explain how these inequalities emerged, how they persist, why they matter, and what we can do to close the gaps.

## Participation in the Innovation Economy

Fundamentally, economists and the public care about innovation, because it is a critical factor in economic growth, wealth generation, and higher living standards. If we consider the components of economic growth—labor, capital, and total factor productivity—innovation can substantially affect each one. In 1957, economist Robert Solow demonstrated that aggregate economic growth owed more to innovation, or technical change, than additional inputs of labor or capital. Solow believed that innovation had an economywide effect and that its impact on the other factors—labor and capital—would be neutral.[8] For decades macroeconomists agreed, and technological progress was viewed as benefiting all workers equally. More recently, theory and evidence suggest that technical change is skill-biased and that its economic benefits favor highly skilled workers. The inequality in wages that arises from this process is a core feature of the more general debate about inequality today.[9]

Many of the key measures of the innovation economy track the participation of *innovators*. The National Science Foundation (NSF), for example, defines the "science and engineering (S&E) workforce" by the number of participants in science and engineering occupations, by the number of holders of science and engineering degrees, and by the use of technical expertise on the job.[10] In addition to educational, occupational, and income metrics, we can measure participation in the innovation economy via patent holders. Data on patents recorded and disseminated by the US Patent and Trademark Office (USPTO) are available from 1790 to the present and provide a relatively consistent historical metric.[11] While the NSF collects demographic data such as gender, race, and ethnicity, such factors are not recorded in patent data. However, my colleagues and I have developed or taken advantage of new methods for inferring which historical and contemporary patents were granted to women and African Americans from 1966 to 2014.[12]

As economists measure innovation's contribution to the economy with increasing precision, it is clear that innovation's importance is growing.[13] In 2013, the NSF calculated that the innovation economy comprised roughly 6 to 21 million workers.[14] These innovation workers earn substantially more than the median income for all workers. In 2014, the median innovation worker earned $81,000, compared to $36,000 for all workers. Innovation economy jobs also are growing faster than in other sectors, and unemployment rates are lower. In February 2013, the unemployment rate for scientists and engineers was 3.8 percent, compared to 4.3 percent for all college graduates and 8.1 percent for the United States overall.[15] During the Great Recession (2007–2009), moreover, the US workforce contracted; however, the innovation workforce was less affected by the overall economic contraction.[16] Amid the recession, the income gap between innovation workers and the general labor force also widened. In 2012, innovation economy earnings were double those of other workers; by 2014, the median innovation worker earned an additional 25 percent more than the median worker in the general labor force.[17] Across a number of measures, the science-based innovation workforce provides a tremendous boost to the overall economy.

Within the innovation economy, however, both participation and salaries vary greatly by gender, race, and ethnicity. In what follows, I examine how the racial and gender gaps are manifest throughout different stages of the innovation process. I provide longitudinal, quantitative evidence to outline the nature and scope of these gaps over time. I then complement this statistical picture with historical and contemporary examples from individual women and African American innovators who were impacted by racial and gender discrimination during the innovation process. This analysis across different scales illuminates both the macroeconomic impact and lived experience of the innovation gap in pink and black.

## Participation Gaps throughout the Innovation Ecosystem

At the risk of oversimplifying a complicated, nonlinear process, it helps to imagine that an individual participates in the innovation economy by passing through three stages. First, innovation typically begins with formal education or an apprenticeship. An innovator needs to master the specialized canon of knowledge in his or her chosen technical field, increasingly through the acquisition of an advanced degree in a STEM field. Second, workers in the innovation economy participate in actual invention in corporate research facilities, university laboratories, government agencies, or sometimes in garages or other informal workspaces. Finally, innovation, or the commercialization of invention, occurs when an inventor sells or licenses her patent, or launches a new start-up or business unit to profit directly from the development of the invention. The innovation gap in pink and black is present, to varying degrees, in all three of these stages.

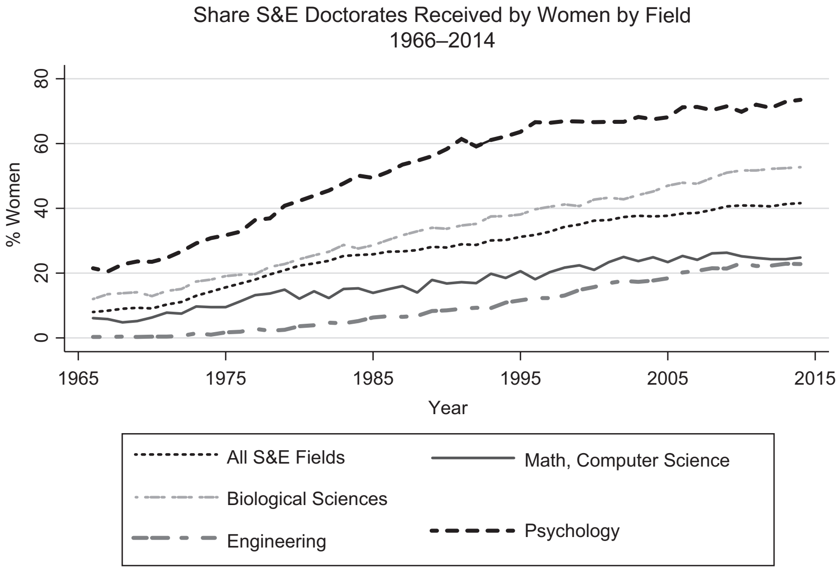
### The Preparation and Education Gap

The first stage in participating in the innovation economy is obtaining a formal education or an apprenticeship. Historically, women and African Americans have been denied equal access to training in STEM fields. When the first agricultural and mechanical colleges appeared in the 1870s, women were discouraged from enrolling and were prevented from joining professional engineering societies. Women first began to enter the coeducational technical universities and technical job training programs during World War II's manpower shortage; the Society for Women Engineers was founded shortly thereafter in 1950. Persistent sexism in engineering education and internships still dissuades many women from pursuing engineering degrees, while workplace discrimination encourages many women engineers to eventually exit the field. As we will see, women have increasingly pursued undergraduate and advanced technical degrees, but their numbers are nowhere near gender parity.[18]

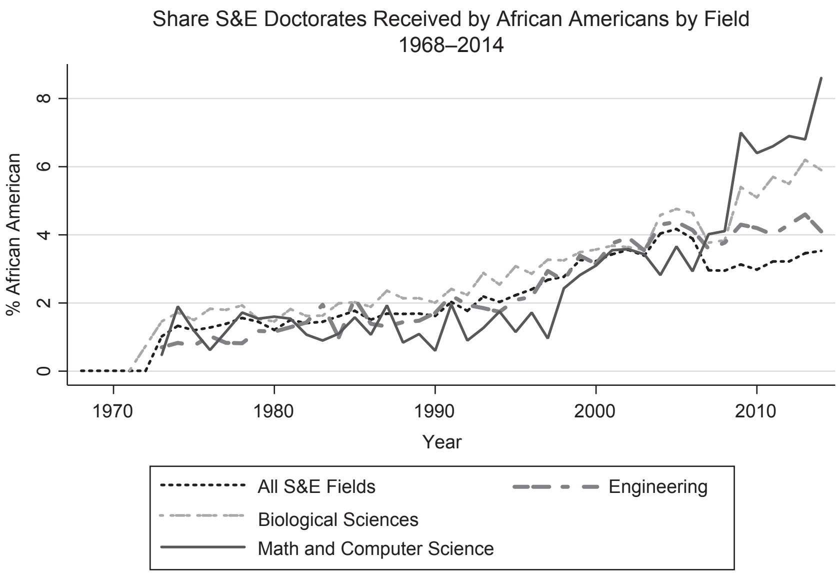
Similarly, African Americans have historically been denied equal access to educational opportunities. Before the Civil War, most enslaved African Americans were systematically denied simple literacy for fear that education would lead to rebellion. Even with the postbellum establishment of black colleges and technical schools—such as Virginia's Hampton Institute (1868) and Alabama's Tuskegee Institute (1881)—freed men and women generally had fewer opportunities for formal education and technical training. Aspiring black inventors were not welcome at the mainstream technical associations; they were also denied apprenticeships by white tradesmen and generally barred from entering the "shop culture" of machinists and telegraphers that was a crucial training ground for many inventors. The civil rights movement precipitated desegregation of public universities in the 1950s and 1960s, and the National Society of Black Engineers emerged soon afterward during the 1970s. However, persistent racial bias in admissions criteria has continued to work against the equal participation of African Americans in the STEM fields.[19]

Women and African Americans have enjoyed significantly improved access to technical training over the last few decades, but an education gap remains. Women and African Americans have increasingly been involved at the beginning of the innovative process, which is at the stage of doing basic research that undergirds changes in the stock, flow, and direction of knowledge (figure 12.1). Between 1970 and 2014, the share of PhDs in S&E fields awarded to women grew substantially, from just 9 percent to 41.6 percent. Over the same period, the share of S&E PhDs awarded to African Americans, though small, more than tripled, from 1 percent to 3.5 percent. We see similar trends for master's and bachelor's degrees.[20]

Increases among women and African Americans, however, have not been uniform across fields of study. In particular, women and African American doctoral recipients have tended to gravitate toward psychology and the life sciences, and to avoid engineering. For example, in 2014, women accounted for 73.5 percent of psychology doctorate degrees. Alternatively, women have traditionally received the lowest share of doctoral degrees in engineering; that figure was just 22.8 percent in 2014. Similarly, among STEM fields, the highest share of African American doctorates was in psychology




Source: NSF NCSES; NCES data
Note: Earth sciences include atmospheric and ocean sciences; biological sciences include agricultural sciences.




Source: NSF NCSES, Survey of Earned Doctorates

**Figure 12.1**

Share of S&E doctorates received by women and African Americans by field.

(7.9 percent), and the lowest was in engineering (1.7 percent). These disciplinary differences are important, because engineering is the discipline most closely associated with patenting.

Clearly, there are persistent barriers to women and African Americans pursuing advanced degrees in STEM fields in general and in engineering in particular. But what does this *education gap* look like in practice? Jennifer Selvidge, a senior honors student in materials engineering at MIT, captured the frustrations of many women and African Americans in her 2014 article “Pushing Women and People of Color out of Science before We Go In.” She reported being told “hundreds of times” that, as a woman, she did not deserve to be at MIT and that metallurgy was a “man’s field.” She endured sexual harassment by her male teaching assistants and witnessed male professors attempting to publicly humiliate the few women professors in her department. She observed students of color being actively advised to change majors and leave her department; she also heard a teaching assistant argue that “black Americans are genetically inferior due to slavery era breeding practices.” And this was at the leading engineering school in the country, if not the world.[21]

America will not fully realize its scientific potential and ever higher economic growth and living standards unless we encourage more women, African Americans, and other underrepresented groups to earn degrees in STEM fields and train for STEM careers. Indeed, the education gap in pink and black—that is, the limited pool of technically trained women and African Americans—helps explain the gaps in the second and third stages (invention, commercialization) of the innovation process.

## The Invention Gap

Invention is the second stage of participation in the innovation economy. As with the education gap, there are historical and structural barriers underlying the invention gap. For centuries, individual women and African Americans were unwelcome in the white, male culture of the corporate R&D labs and were barred from joining professional scientific and engineering societies. Discrimination thus deprived them of the social capital and connections required to advance their careers and develop their inventions.[22]

Legal access to the US patent system offered greater but still limited opportunities 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; decades before emancipation and universal suffrage, women and (free) blacks could, and did, invent and earn US patents.[23] Still, women and African Americans did not have equal protection under the patent laws. Although free blacks were allowed to obtain patents, the Patent Office refused to grant patents to enslaved blacks. Moreover, laws in many states assigned all marital property rights to husbands and prohibited married women from owning or controlling patents in their own names.[24]

Contemporary measures of inventive activity among women and African Americans reveal evidence of increased participation, but also continued barriers to access. We can measure the relative participation of women and African Americans in invention through data on employment, salaries, and patents.

In the realm of technical employment, women's participation in the invention stage has grown modestly. Between 1993 and 2015, women in S&E occupations rose from 23 percent to 28 percent.[25] Still, there were significant intersectional differences. White women constituted 18 percent of the total, while African American women accounted for just 2 percent.[26]

Digging into the data of what women and African American doctorate holders actually do on the job raises additional concerns about their participation as innovators (figure 12.2). First, the majority of such graduates are not employed in science and engineering occupations at all. Additionally, while more than half the people in S&E-related occupations are women scientists and engineers, they tend to be in supporting roles, such as technicians and precollege teaching, rather than inventing roles. Moreover, differences in fields of educational training are compounded in the career trajectories of women and African Americans with S&E degrees. More than two-thirds of psychologists are women, and women are more concentrated in life sciences relative to men but less concentrated in computer and mathematical sciences.[27]

Similarly, African American scientists and engineers make up just 4.8 percent of S&E occupations. African American scientists and engineers also are more concentrated among social and related scientists and computer systems analysts than in other occupations. Among S&E-related occupations, African American scientists and engineers are more concentrated in health-related occupations and in precollege teaching than in other occupations. Almost twice as many African American scientists and engineers are in non-S&E occupations as are in S&E occupations.

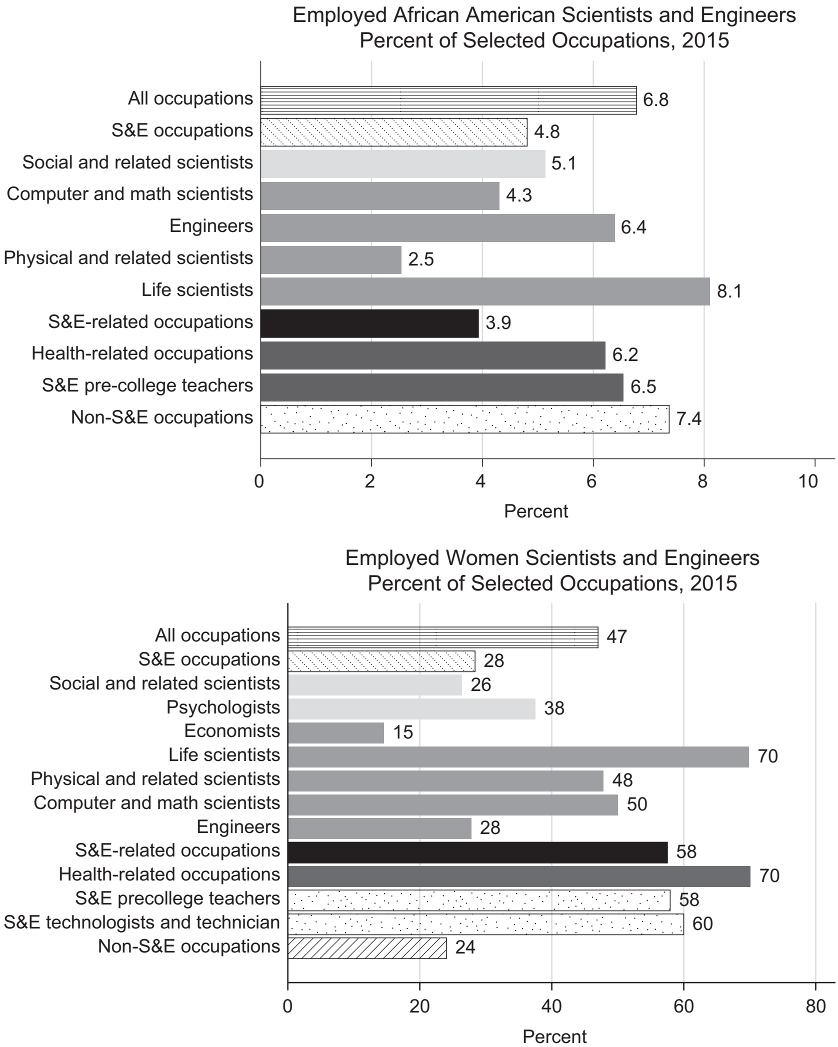



**Figure 12.2**
Employed women and African Americans in S&E fields, 2015.
Source: NSF WMPD 2017 Digest.

Problems of retention also plague the innovation economy. Women leave for various reasons, including childcare, family leave policies, and workplace environment.[28] Such departures have implications for the earnings of women innovators. On average, women's wages will be lower outside the innovation economy, so the departures of technically trained women tend to exacerbate the income inequality that already exists between the innovation and noninnovation economy.

While employment rates are increasing among women and underrepresented minority scientists and engineers, unemployment rates vary significantly by gender and by racial and ethnic group (figure 12.3). The unemployment rate for African American women is higher than the unemployment rate overall, nearly double that of all scientists and engineers and more than double that of white women scientists and engineers. Unemployment for underrepresented minority men, at just above 4 percent, is higher than for white and Asian men and higher than the average for all scientists and engineers.[29] Similar to the data on occupations, scientists and engineers with greater experiences of unemployment will likely be poorer and less able to accumulate wealth than their counterparts with lesser experiences of unemployment.

Yet another gap related to invention is based on the kinds of institutions in which women and African Americans are employed (figure 12.4). Most scientists and engineers are employed in industry. Apart from underrepresented minority men, the second and third sectors of employment are education and government. On average, government and education salaries are lower than those in industry, further deepening the income inequality among S&E workers. Most importantly, while many workers in government laboratories work hard at patenting, they have binding constraints relative to their private sector peers and are less likely to commercialize their inventions. This can have even greater implications for wealth inequality in the innovation stage of technology commercialization.

Salary and income data indicate other markers of inequality in innovation jobs. The earnings or income gap between workers in the innovation economy and the overall economy is substantial. A worker in the innovation economy earned 63 percent more than the average American worker in 2014.[30] To be sure, this divergence in income is consistent with and related to overall income inequality in the United States.

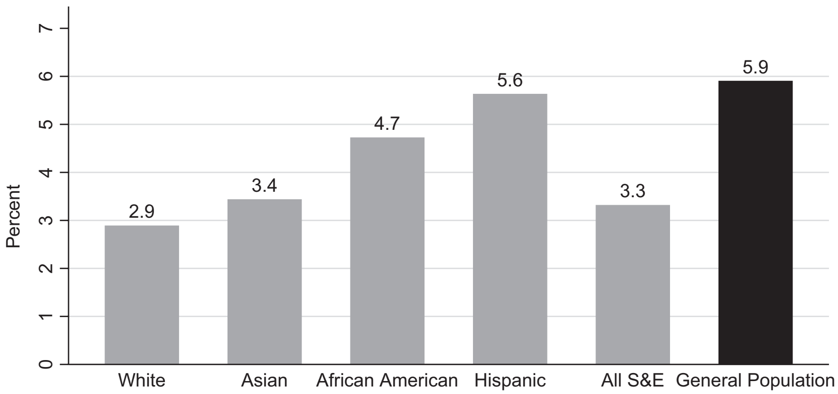



**Figure 12.3**
Unemployment rates among scientists and engineers, 2015.
Source: NSF WMPD 2017 Digest. Note: The general population consists of the U.S. civilian noninstitutional population of 16 years and over. Unemployment rates based on individuals actively seeking employment.

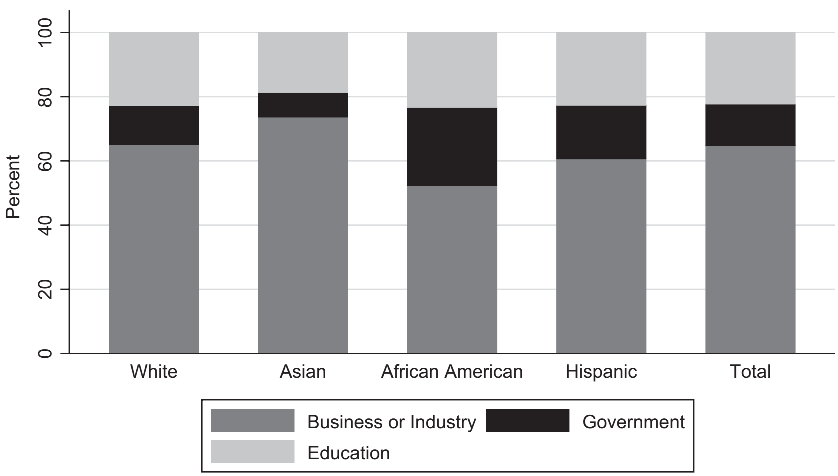



**Figure 12.4**
Employment sector of scientists and engineers by race and ethnicity, 2015.
Source: NSF WMPD 2017 Digest.

Just as incomes vary between innovation and the rest of the economy, they also vary among those within the innovation economy, particularly by gender and race. While the median salary for men in the innovation economy in 2010 was $80,000, it was only $53,000 for women. The gap between the median salary for African Americans and whites is not as large as it is 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.[31] Overall, there are still significant gender and racial gaps, but they appear to be closing. In 2015, for example, the median salary was $87,000 for men and $62,000 for women, or 71 percent of the median male salary.[32] In 2015, this share had moved only slightly to 79 percent. For S&E occupations, this share narrows to 92 percent.

Patent data provide yet another means of measuring inequality in inventive activity.[33] In earlier research, my colleagues and I demonstrated that women and African Americans lag far behind other US inventors with respect to patent activity. Using USPTO data from 1970 to 2006, we calculated that patent output for all US inventors is 235 patents per million; for women it is forty patents per million; and for African Americans it is six patents per million.[34] Moreover, economist Raj Chetty has found that a propensity to patent is closely associated with prior exposure to inventive activity and multigenerational income and wealth disparities. In other words, 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.[35] Together, these two findings suggest a perpetual and intractable invention gap that is difficult to close.

Overall, women and African Americans are less likely to work in science and engineering jobs, are paid less for doing those jobs, and are less likely to earn US patents. But how is this discrimination manifested in the workplace? The discrimination underlying the invention gap was on public display in 2017 when Google engineer James Damore wrote an internal memo that leaked and went viral arguing that women were underrepresented in technology careers because of "inherent psychological differences."[36] A few weeks later, a former Google software engineer, Kelly Ellis, and two other women sued Google, alleging discrimination in both pay and promotion. These incidents followed a spring 2017 report in which the US Department of Labor investigated systemic discrimination against women at Google.[37]

Although the courts have yet to rule on the case, one could hypothesize that unequal salaries contribute to women's anemic pursuit of S&E degrees and careers, thereby perpetuating their underrepresentation. Consequently, men like Damore—who, because of the gaps, have never worked on diversified teams—may continue to perpetuate the stereotype that women and minorities simply do not belong in the high-tech professions. It is a vicious cycle.

### The Innovation Gap

The commercialization of inventions is the third and final stage of participation in the innovation economy. This stage is also where diverse groups—women and underrepresented minorities—are most scarce. The preceding section showed that women and African Americans are less likely to have a patent and to work in the innovation economy. Given these gaps, it is reasonable to assume that the commercialization gap is wide from the start. Indeed, women and African Americans are less likely to found a firm based on a patented invention or to be a venture capitalist or tech investor in early-stage start-ups. Therefore, they are less likely to profit from the commercialization stage.

Commercialization requires drawing on financial and social capital to introduce the invention into society. Historically, women and African Americans have had diminished access to these resources and so have developed alternative strategies.[38] For example, women and African American inventors once purposefully obscured their identities in order to sidestep discrimination and profit from their inventions. Garrett Morgan, an African American inventor based in Cleveland, correctly surmised that white consumers would be skeptical of buying products from a black inventor. At the turn of the twentieth century, Morgan hired white actors to portray him in order to sell his gas mask, traffic signal, and other products.[39] Discrimination also forced women and African Americans into bad deals or to forego commercialization entirely. For example, in 1888, Ellen Eglin of Washington, D.C., sold her patented clothes wringer to a patent agent for a mere eighteen dollars rather than build a business around the patent.[40]

Social conditions have improved enormously over the last century, but today's women and African American inventors continue to struggle with commercialization. Contemporary inventors have four methods of generating income from an invention: (1) engage in entrepreneurship and start a new firm (or business unit) to develop, manufacture, and sell the invention; (2) assign (i.e., sell) the patented invention for a lump sum; (3) license the patented invention to another manufacturer and collect royalties until the patent expires; or (4) sue patent infringers to collect owed royalties and damages as a so-called patent troll. Economists can access data on certain of these approaches but not others. Consequently, I measure the innovation gap by focusing on data regarding entrepreneurship, firm ownership, patent assignments, and wealth accumulation from assets developed in the innovation economy.

Commercialization, particularly entrepreneurship and equity ownership of high-tech firms, is the stage of the innovative process where entrepreneurs find the largest pecuniary gains. Those who own equity stakes in high-tech companies—for example, angel and venture capital investors, founders, and employees with stock options—stand to profit greatly from initial public offerings, acquisitions, mergers and acquisitions, stock splits, and other liquidity events. Among the *Forbes* list of richest people in the world, five of the top ten derive their wealth primarily from the innovation economy. However, all ten are men, and none are black.[41]

The high market valuations and sheer size of transactions among high-tech firms mean that those with equity ownership stakes stand to profit handsomely. For example, Apple's market capitalization recently hit the $1 trillion market cap, which is greater than the size of the economy (GDP) of a number of the world's richest countries, including Argentina, Sweden, Switzerland, and Turkey.[42] The nine tech firms with initial public offerings (IPOs) in 2017 are collectively valued at roughly $36 billion.[43]

However, it is difficult to find women and African Americans among the ranks of venture capitalists, entrepreneurs, and (senior) management teams. For example, according to a study by the National Venture Capital Association (NVCA) in 2015, only 11 percent of venture capitalists were women, and only 2 percent were African Americans.[44] The NVCA also reported that in 2014, less than 7 percent of US venture capital funds were invested in businesses founded by women, and less than 1 percent were invested in businesses founded by African American women.[45] A different study by First Round Capital provided similarly bleak numbers: female CEOs receive only 2.7 percent of all venture funding, while women of color get virtually none—0.2 percent.[46]

This homogeneity extends from the investors to high-tech entrepreneurs and executives. Women and African Americans often work in the legal and marketing departments of high-tech firms, but there are few women in senior technical roles, in executive positions, or on boards of directors. For example, in 2014, *Fortune* ranked the relative diversity of several large tech firms based on recently released demographic data. With respect to women executives, Indiegogo was ranked highest, with women constituting 43 percent of leadership roles. Cisco and Pinterest were ranked lowest, with only 19 percent women in these roles. Women constituted just 18.7 percent of boards of S&P 500 firms in 2014, which was up from 16.3 percent in 2011.[47]

This lack of gender, racial, and ethnic diversity in the innovation economy is often attributed to a lack of mentors and social networks, implicit bias, and, to a lesser extent, the feeble pipeline of potential entrepreneurs, executives, board members, and funders.[48] Again, we see a vicious cycle: there are few women and African Americans in high tech, so there are fewer mentors, social networks, and colleagues helping to shepherd a more diverse set of investors and entrepreneurs into the innovation economy.

With regard to commercialization, these findings are troubling because a large and growing literature suggests that more diverse teams produce better outcomes.[49] For example, First Round Capital reports that founding teams that include a woman outperform their all-male peers by 63 percent.[50] This homogeneity among VCs, and the resulting suboptimal financing of projects, is clearly a bad outcome for women and African American founders and entrepreneurs, but also for the overall economy, which depends on the commercialization of new ideas to raise incomes and living standards.

Patent assignment is another simple measure of potential commercialization recorded in USPTO data. Patents are typically sold by independent or employee inventors to entities such as corporations, government agencies, universities, and research institutions. For example, venture capitalists often prefer investing in founders with patents and patents pending, and they typically require them to assign the patents to the start-up as a condition of investment. In addition, as part of their employment contracts, corporate, university, and government employees who produce inventions on the job are contractually obligated to immediately assign their patents to their employers (usually for one dollar) once they are issued by the USPTO. The assignees (the buyers) may or may not choose to commercialize these inventions, so assignments are an admittedly imperfect proxy for commercialization.[51]

Economists have particularly good data on corporate and government patent assignments as a measure of the commercialization gap. The previous section showed that women and African Americans are less likely to earn patents. But they are also less likely to sell those patents. Women inventors' odds of assigning a patent at issue to a public firm are 51 percent lower than men's odds; similarly, African American inventors' assignment odds are 46 percent lower than other US inventors' odds.[52]

In addition, the high concentration of African American scientists and engineers in the government sector (see figure 12.4) has implications for wealth accumulation and inequality. The Bayh-Dole Act of 1980 permitted universities and corporations to own and commercialize any patents earned as a result of federal research funding. However, the US government still owns any patents earned by federal employees.[53] In general, commercialization is more difficult in the government (versus the private) sector due to strict ethics policies and is less likely to occur due to lack of incentives and risk aversion among government employees and contractors.[54] Moreover, African Americans who begin assigning their patents to government entities are more likely to continue to assign to government entities rather than corporate entities, unlike their white coinventors on the original government-assigned patents.[55] Therefore, African American scientists and engineers, who tend to be more concentrated in government service, are less likely to realize financial returns from their patents.

Overall, women and African American inventors are significantly less likely than their US inventor counterparts to obtain and commercialize a patent. Women and African Americans are also underrepresented among venture capitalists, are less likely to receive start-up capital and launch new firms, and thus are less likely to own equity stakes in high-tech firms as a founder, senior manager, executive, or board member. In short, women and African Americans face significant challenges when it comes to commercializing their inventive activity. But how is this manifest in the real world? What does this innovation gap look like in practice?

This innovation gap was in the public eye in 2012 when Ellen Pao sued her employer, the noted venture capital firm Kleiner Perkins Caufield & Byers, for gender discrimination. Pao alleged that the firm's male partners excluded her from key meetings and harassed her when she spoke out; she was ultimately passed over for promotion. In the midst of the lawsuit, she became the CEO of Reddit and faced additional gender-related harassment and threats of violence when she called for the removal of objectionable content from the site's message boards. Pao ultimately lost her discrimination lawsuit, but in the process she has become an advocate for diversity and inclusion, and a symbol of the difficulties women face in the male-dominated high-tech and venture capital industries.[56] In the end, systemic gender and racial discrimination in the high-tech and venture capital sectors drives a wedge between good ideas, capital, and the commercialization of those ideas.

## Why Does It Matter?

Women and African Americans are underrepresented in the innovation economy. At each stage of the innovation process—including technical training, employment, patenting, financing, entrepreneurship, and commercialization—women and African Americans participate at lower rates than their counterparts.

Why does it matter? First, because of these gaps, our economy is not as strong as it should be. These findings suggest a misallocation of resources that could contribute to suboptimal rates of economic growth. For example, we know that coed patent teams are more productive than single-sex teams with respect to the most valuable patents; likewise, start-up teams that include a woman outperform their all-male peers.[57] There is an opportunity cost to gender and racial discrimination, so patent teams, start-up firms, and the overall economy will continue to underperform without more emphasis on diversity and inclusion.

Second, because of these gaps, women and Africans Americans have not been able to enjoy their fair share of innovation's ample rewards. As we have seen, relative to other sectors, the innovation economy generates high incomes and considerable wealth. In addition, the leaders of the high-tech sector—including Bill Gates, Elon Musk, Mark Zuckerberg, and Jeff Bezos—wield considerable social, cultural, and political influence. However, if women and African Americans are disproportionately absent from the sector, they are deprived of their fair share of opportunity, wealth, and influence. Indeed, inequality in the innovation sector undermines the American ideals of equal opportunity and a shared responsibility to achieve shared prosperity.

Third, these gender and racial gaps raise fundamental concerns related to growing income and wealth inequality. In the economics literature, there is mounting evidence of increases in both types of inequality. For example, income-tax data suggests that levels of income inequality are higher now than they were during the Gilded Age.[58] In just the period from 1993 to 2011, real income growth was nearly ten times higher for the top 1 percent compared to the bottom 99 percent—57.5 percent compared to 5.8 percent.[59]

With its high salaries, stock options, and huge IPOs, the innovation economy has been a driver of this overall income and wealth inequality. However, there are also huge income and wealth inequalities *within* the innovation economy. The financial industry notwithstanding, the innovation sector likely offers the starkest examples depicting that, over time, the rate of return to financial capital (dividends, interest, and especially capital gains) strictly exceeds the rate of return to human capital (wages).[60] We can see this income and wealth divergence among the sector's highly skilled (but salaried) software programmers, marketers, and lawyers, and the billionaire founders and venture capitalists who own sizable equity stakes in publicly traded firms. Women and African Americans have a harder time even entering the innovation sector, and those who do tend to be salaried employees versus owner-capitalists. Clearly, the income and wealth gap within, and relative to, the innovation economy is also related to overall income and wealth inequality in the United States.

Why would economists and the public care about these distributional issues? First, with respect to well-being, individuals assess their incomes, or economic well-being, in relative rather than absolute terms. Large and sustained divergence in incomes within the innovation economy may result in additional discontent and turmoil within that sector. In addition, workers in other sectors of the economy may become increasingly demoralized as they witness the huge income and wealth gains—and disproportionate political influence—of the top tier of the innovation sector. It is rare for economic policymaking bodies and leaders—such as the IMF, former Council of Economic Advisers chair Alan Krueger, and former Federal Reserve chair Janet Yellen—to discuss income and wealth inequality and its implications publicly, but recently they have done so and are doing so increasingly.[61] Three consequences are of particular concern to economic policymaking bodies: a fall in intergenerational mobility, families borrowing beyond their means (which could lead to another financial crisis), and political decisions that are likely to result in policies that lead to even lower growth. Any of these frustrations could eventually boil over into more social unrest, which in turn may lead to lower growth rates.

## Conclusion: What Is to Be Done?

How might we address the underrepresentation of women and African Americans in the innovation economy? How might we intervene at each stage of the innovation process? Is there a role for policy?

Before suggesting any policies, researchers should first calculate and quantify the opportunity cost associated with current practice. Recent research finds that women's underrepresentation in engineering, development, and design jobs explains much of the patent gap between men and women and that closing the gap could increase US GDP per capita by 2.7 percent.[62] In an analysis of the NSF's Survey of Earned Doctorates, I have also suggested that the inclusion of more women and African Americans in the initial stages of the innovation process could increase GDP per capita by 0.64 to 3.3 percent.[63] Although this research focuses on BA and PhD holders, the policy prescription is similar: address barriers that keep women and African Americans from engaging more fully in the innovation economy.

Another modest policy proposal involves data. It is still difficult to obtain demographic data on patentees, so there should be a sustained collaborative effort by government agencies to make such data available to researchers. Currently, there is an effort to match patent data to census data at secure federal Research Data Centers (RDCs). Similarly, the UMETRICS initiative tracks federal spending on science and technology research projects, with some additional demographic data available via the RDCs. These data initiatives should be sustained and extended.

Finally, policymakers should specifically focus on addressing diversity and inclusion in patenting. Since most patenting occurs within firms, such policy prescriptions will likely be developed and implemented by the firms themselves. Fortunately, there is a compelling business case for reforms. Diverse, coed patent teams are more productive than homogeneous, single-sex teams, so enlightened workplace inclusion policies are good for high-tech workers but also good for business.

Economists need to collect more data and conduct more research to address the innovation gap adequately, recommend appropriate changes, and reallocate resources better. The broader inclusion of women and African Americans in the innovation economy should help us realize our innovation potential and, as a result, higher living standards and greater shared prosperity. There is much to be gained from this effort and much to be lost if we fail to act. If women and African Americans continue to be underrepresented in the innovation economy, we may face a future with lower rates of economic growth, widespread income and wealth inequality, a political process influenced only by top earners, and ultimately, social unrest.

## Notes

1. An earlier version of this essay was presented at the Institute for New Economic Thinking annual conference as a keynote address in April 2014 in Toronto. The author is grateful for thoughtful comments from participants in the conference. The author also thanks Jan Gerson, Alex Ginsberg, and Madelaine Irwin.

2. Paul M. Romer, "Increasing Returns and Long-Run Growth," *Journal of Political Economy* 94, no. 5 (October 1986): 1002–1037. Prior to Romer, economists thought of innovation as an exogenous phenomenon that was generated outside of economic models. For example, see Robert M. Solow, "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics* 39, no. 3 (August 1957): 312–320; Zvi Griliches, "Hybrid Corn: An Exploration in the Economics of Technological Change," *Econometrica* 25 (October 1957): 501–522.

3. Zorina Khan and Kenneth Sokoloff, "Schemes of Practical Utility: Entrepreneurship and Innovation among 'Great Inventors' in the United States, 1790–1865," *Journal of Economic History* 53, no. 2 (June 1993): 289–307; Joel Mokyr, "Long-Term Economic Growth and the History of Technology," chapter 17 in *Handbook of Economic Growth*, vol. 1, part B, ed. Philippe Aghion and Steven Durlauf (Amsterdam: Elsevier, 2005), 1113–1180; Ross Thomson, *Structures of Change in the Mechanical Age: Technological Innovation in the United States, 1790–1865* (Baltimore: Johns Hopkins University Press, 2009).

4. "Science and Engineering Indicators 2016, Chapter 3," National Science Foundation, 2016, accessed 13 September 2017. In this chapter, the terms "innovation economy," "science and engineering (S&E) economy," and "S&E occupations" will be used interchangeably.

5. To be sure, other forms of discrimination in the American innovation economy exist, including discrimination against various ethnic groups, religious identities,

and sexual orientations. However, this chapter focuses exclusively on the underrepresentation of women and African Americans.

6. There is an abundant historical literature documenting both the triumphs and struggles of women and African Americans engaged in technological innovation. For example, see Anne L. Macdonald, *Feminine Ingenuity: Women and Invention in America* (New York: Ballantine Books, 1992); Autumn Stanley, *Mothers and Daughters of Invention: Notes for a Revised History of Technology* (Metuchen, NJ: Scarecrow Press, 1993); Rayvon Fouché, *Black Inventors in the Age of Segregation: Granville T. Woods, Lewis H. Latimer, and Shelby J. Davidson* (Baltimore: Johns Hopkins University Press, 2003); Patricia Carter Sluby, *The Inventive Spirit of African Americans: Patented Ingenuity* (Westport, CT: Praeger, 2004).

7. News outlets regularly report on the lack of diversity in the venture capital industry and the paucity of women and African Americans who serve as executives and board members for high-tech companies. For example, see Anna Wiener, "Why Can't Silicon Valley Solve Its Diversity Problem?" *New Yorker*, 26 November 2016, accessed 17 July 2017, http://www.newyorker.com/business/currency/why-cant-silicon-valley-solve-its-diversity-problem. Also see the U.S. Equal Employment Opportunity Commission, "Diversity in High Tech," May 2016, accessed 17 July 2017, https://www.eeoc.gov/eeoc/statistics/reports/hightech/upload/diversity-in-high-tech-report.pdf.

8. Solow, "Technical Change and the Aggregate Production Function."

9. For a good summary of this debate in the growth literature, see Giovanni L. Violante, "Skill-Biased Technical Change," in *The New Palgrave Dictionary of Economics*, 2nd ed., ed. Steven N. Durlauf and Lawrence E. Blume (London: Palgrave Macmillan, 2008).

10. NSF collects data on S&E students, graduates, and workers using a variety of surveys and sources, including the NSF Survey of Earned Doctorates (SED) and the National Center for Education Statistics (NCES) Integrated Postsecondary Education Data System Completions Survey. In addition to collecting data on fields of study, I have assembled NSF data on doctoral degrees earned by women (1966 to 2014) and African Americans (1968 to 2014).

11. This chapter focuses on utility (versus design) patents, which constitute the largest category of issued patents. A utility patent is issued for any new and useful process, machine, manufacture, composition of matter, or any new and useful improvement thereof.

12. Lisa D. Cook, *The African American and Women Inventors and Patents Data Set* (Stanford University, August 2003), last revised in November 2008, extended to women inventors, August 2009.The original data set did not include a separate, distinct file of women inventors. Women inventors were separately identified in 2009, and the term "women" was added to the data set. Lisa D. Cook and Chaleampong

Kongcharoen, "The Idea Gap in Pink and Black," NBER working paper no. 16331, September 2010.

13. See, e.g., Erik Brynjolfsson and Andrew McAfee, *Race against the Machine: How the Digital Revolution Is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy* (Lexington, MA: Digital Frontier Press, 2011); Stephen D. Oliner and Daniel E. Sichel, "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?" *Journal of Economic Perspectives* 14, no. 4 (2000): 3–22; Stephen D. Oliner, Daniel E. Sichel, and Kevin J. Stiroh, "Explaining a Productive Decade," FEDS Working Paper no. 2007–63 (January 2007), https://ssrn.com/abstract=1160248 or http://dx.doi.org/10.2139/ssrn.1160248.

14. The definition varies based on the three ways NSF measures the S&E workforce. In the United States in 2013, roughly 5.74 million college graduates were employed in S&E occupations, and roughly 21.1 million college graduates had a bachelor's or higher-level degree in an S&E field. "Science and Engineering Indicators 2016, Chapter 3."

15. Ibid.

16. Ibid.

17. Ibid.; "Science and Engineering Indicators 2014, Chapter 3," National Science Foundation, 2014, accessed 13 September 2017, https://www.nsf.gov/statistics/seind14/index.cfm/chapter-3/c3h.htm.

18. On gender discrimination in technical education and the professions, see Ruth Oldenziel, *Making Technology Masculine: Men, Women, and Modern Machines in America, 1870–1945* (Amsterdam: Amsterdam University Press, 1999); Amy Sue Bix, *Girls Coming to Tech! A History of American Engineering Education for Women* (Cambridge, MA: MIT Press, 2014); and Carroll Seron, Susan S. Silbey, Erin Cech, and Brian Rubineau, "Persistence Is Cultural: Professional Socialization and the Reproduction of Sex Segregation," *Work and Occupations* 43, no. 2 (December 2016): 178–214.

19. On racial discrimination in technical education, see David E. Wharton, *A Struggle Worthy of Note: The Engineering and Technological Education of Black Americans* (Westport, CT: Greenwood Press, 1992); Bruce Sinclair, ed., *Technology and the African-American Experience: Needs and Opportunities for Study* (Cambridge, MA: MIT Press, 2004); Mabel O. Wilson, *Negro Building: Black Americans in the World of Fairs and Museums* (Berkeley: University of California Press, 2012); and Amy E. Slaton, *Race, Rigor, and Selectivity in U.S. Engineering: The History of an Occupational Color Line* (Cambridge, MA: Harvard University Press, 2010).

20. While the focus of this section is on S&E doctorates, most commercialized inventions originate from those with bachelor's degrees and master's degrees. "Doctorate Recipients from U.S. Universities," National Science Foundation, 2017, accessed 13 September 2017, https://www.nsf.gov/statistics/2017/nsf17306/static

/report/nsf17306.pdf; "Doctorate Recipients from United States Universities: Summary Report 2000," National Science Foundation, 2001, accessed 13 September 2017, http://files.eric.ed.gov/fulltext/ED459639.pdf.

21. Jennifer Selvidge, "Pushing Women and People of Color Out of Science before We Go In," *Huffington Post*, 18 September 2014, accessed 18 September 2017, http://www.huffingtonpost.com/jennifer-selvidge/pushing-women-and-people-_b_5840392.html.

22. Lisa D. Cook, "Inventing Social Capital: Evidence from African American Inventors, 1843–1930," *Explorations in Economic History* 48, no. 4 (December 2011): 507–518.

23. For example, in 1809, inventor Mary Kies was the first woman to receive a US 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 US patent in 1821, for a dry-cleaning process. On Kies, see United States Patent Office, *Women Inventors to Whom Patents Have Been Granted by the United States Government, 1790 to July 1, 1888* (Washington, DC: Government Printing Office, 1888). On Jennings, see Sluby, *Inventive Spirit of African Americans*, 15–17. On the egalitarian nature of the US patent system, see B. Zorina Khan, *The Democratization of Invention: Patents and Copyrights in American Economic Development, 1790–1920* (New York: Cambridge University Press, 2005).

24. On discriminatory patent laws and policies, see Matilda Joslyn Gage, "Woman as an Inventor," *North American Review* 136, no. 318 (May 1883): 478–489, especially 488; Henry Baker, "The Negro as an Inventor," in *Twentieth Century Negro Literature*, ed. D. W. Culp (Naperville, IL: J. L. Nichols, 1902): 399–413, especially 400; Carroll Pursell, "Women Inventors in America," *Technology and Culture* 22, no. 3 (July 1981): 545–549, especially 546; Steven Lubar, "The Transformation of Antebellum Patent Law," *Technology and Culture* 32, no. 4 (October 1991): 932–959.

25. "Science & Engineering Indicators 2014, Chapter 3."

26. "Women, Minorities, and Persons with Disabilities in Science and Engineering," National Science Foundation, 2017, accessed 14 September 2017, https://www.nsf.gov/statistics/wmpd (author's calculations).

27. "Science & Engineering Indicators 2014, Chapter 3;" "Women, Minorities, and Persons with Disabilities in Science and Engineering."

28. A growing number of researchers are examining why women leave S&E occupations. For example, see "Women, Minorities, and Persons with Disabilities in Science and Engineering"; Julianne Pepitone, "Silicon Valley Fights to Keep Its Diversity Data Secret," *CNN Money*, 9 November 2011, http://money.cnn.com/2011/11/09/technology/diversity_silicon_valley.

29. Underrepresented minorities include scientists and engineers who are black, Hispanic, and American Indian or Alaska Native. While the disaggregated data are not available, the unemployment rates in the innovation economy for these groups are somewhat similar. Data on gender by race and ethnicity are reported in "Women, Minorities, and Persons with Disabilities in Science and Engineering," but the accompanying data do not allow this calculation to be made.

30. "Science & Engineering Indicators 2016, Chapter 3."

31. Salary data for 2010 are from "Science & Engineering Indicators 2014, Chapter 3," and are for full-time workers with the highest degree in an S&E field. If using the measure of S&E occupations, men's median salary is 19 percent higher than women's. Salary data for 2015 are from "Women, Minorities, and Persons with Disabilities in Science and Engineering."

32. "Women, Minorities, and Persons with Disabilities in Science and Engineering," author's calculations. If considering only S&E occupations, the share of female-to-male median salary narrows to 81 percent and ranges from 77 percent for ages 29 and younger to 85 percent for ages 50 to 75. The share of female-to-male median salary is slightly higher in S&E-related occupations, 73 percent, and slightly lower for non-S&E occupations, 69 percent. "Mathematical scientist" is the only occupation in which the median female salary exceeds the male median salary, and the ratio of female-to-male median salary is 1.13.

33. For a variety of reasons, patent data is 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 not to be developed but 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 Jacob Schmookler, *Invention and Economic Growth* (Cambridge, MA: Harvard University Press, 1966); Zvi Griliches, "Patent Statistics as Economic Indicators: A Survey," *Journal of Economic Literature* 28 (1990): 1661–1707; and Adam Jaffe and Manuel Trajtenberg, eds., *Patents, Citations, and Innovations: A Window on the Knowledge Economy* (Cambridge, MA: MIT Press, 2002).

34. Lisa D. Cook, "Inventing Social Networks: Evidence from African American 'Great Inventors,'" working paper, Michigan State University, 2007; Cook and Kongchareon, "Idea Gap in Pink and Black"; Lisa D. Cook, "The Innovation Economy in Pink and Black," working paper, 2014.

35. Alex Bell, Raj Chetty, Xavier Jaravel, Neviana Petkova, and John van Reenan, "The Lifecycle of Inventors," working paper, 13 June 2016, accessed 21 July 2017, http://www.rajchetty.com/chettyfiles/lifecycle_inventors.pdf.

36. Mark Bergen and Ellen Huet, "Google Fires Author of Divisive Memo on Gender Differences," *Bloomberg*, 7 August 2017, accessed 29 September 2017, https://www.bloomberg.com/news/articles/2017-08-08/google-fires-employee-behind-controversial-diversity-memo; Michael Cernovich, "Full James Damore Memo—Uncensored Memo with Charts and Cites," accessed 29 September 2017, https://medium.com/@Cernovich/full-james-damore-memo-uncensored-memo-with-charts-and-cites-339f3d2d05f.

37. Bourree Lam, "The Department of Labor Accuses Google of Gender Pay Discrimination," *Atlantic Monthly*, accessed 29 September 2017, https://www.theatlantic.com/business/archive/2017/04/dol-google-pay-discrimination/522411/.

38. Cook, "Inventing Social Networks."

39. Lisa D. Cook, "Overcoming Discrimination by Consumers during the Age of Segregation: The Example of Garrett Morgan," *Business History Review* 86, no. 2 (summer 2012): 211–234, especially 227–229.

40. Eglin's 1888 letter quoted in Charlotte Smith, "Colored Woman Inventor," *Woman Inventor* 1, no. 1 (April 1891): 3.

41. Luisa Kroll and Kerry Dolan, "Meet the Members of the Three-Comma Club," *Forbes,* 6 March 2018, https://www.forbes.com/billionaires/#26f4dea7251c.

42. Google Finance, *Google.com,* https://finance.google.com/finance; Google public data, world development indicators, *Google.com,* https://www.google.com/publicdata/explore?ds=wb-wdi.

43. Alex Wilhelm, "2017 Tech IPOs Are on a Tear Compared to Last Year," *Techcrunch.com*, 1 May 2017, https://techcrunch.com/2017/05/01/2017-tech-ipos-are-on-a-tear-compared-to-last-year.

44. "Building a More Inclusive Entrepreneurial System," National Venture Capital Association, accessed 29 September 2017, https://nvca.org/wp-content/uploads/delightful-downloads/2016/07/NVCA-2016-Diversity-Report.pdf.

45. "Building a More Inclusive Entrepreneurial System."

46. First Round Capital, cited in Kimberly Weisul, "Venture Capital Is Broken. These Women Are Trying to Fix It," *Inc.*, November 2016, accessed 29 September 2017, https://www.inc.com/magazine/201611/kimberly-weisul/new-face-of-funding.html.

47. Tom Huddleston Jr., "Boardroom Breakthrough: Gender Diversity Is Flourishing among Board Nominees," *Fortune,* 25 September 2014, accessed 29 September 2017, http://fortune.com/2014/09/25/boardroom-breakthrough-gender-diversity-is-flourishing-among-board-nominees.

48. For more information on gender bias, specifically implicit bias, see Sanders and Ashcraft (chapter 17) in this volume.

49. David Rock and Heidi Grant, "Why Diverse Teams Are Smarter," *Harvard Business Review,* 4 November 2016, accessed 29 September 2017, https://hbr.org/2016/11/why-diverse-teams-are-smarter.

50. Weisul, "Venture Capital Is Broken."

51. Joan Farre-Mensa, Deepak Hegde, Alexander Ljungqvist, "What Is a Patent Worth? Evidence from the U.S. Patent 'Lottery,'" 14 March 2017, NBER working paper no. 23268, accessed 8 October 2017, http://www.nber.org/papers/w23268; Catherine L. Fisk, *Working Knowledge: Employee Innovation and the Rise of Corporate Intellectual Property, 1800–1930* (Chapel Hill: University of North Carolina Press, 2009); Philip Mirowski, *Science-Mart: Privatizing American Science* (Cambridge, MA: Harvard University Press, 2011).

52. Cook and Kongchareon, "Idea Gap in Pink and Black"; odds are calculated relative to assignment to an individual.

53. David C. Mowery, Richard R. Nelson, Bhaven N. Sampat, and Arvids A. Ziedonis, *Ivory Tower and Industrial Innovation: University-Industry Technology Transfer before and after the Bayh-Dole Act* (Stanford, CA: Stanford Business Books, 2004).

54. 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 quite stable, and government agencies have traditionally been risk averse; for example, see Gustetic (chapter 7) in this volume.

55. Cook, *African American and Women Inventors.*

56. Ellen Pao, *Reset: My Fight for Inclusion and Lasting Change* (New York: Spiegel and Grau, 2017).

57. Weisul, "Venture Capital Is Broken"; Cook and Kongchareon, "Idea Gap in Pink and Black."

58. Thomas Piketty and Emmanuel Saez, "Income Inequality in the United States, 1913–1998," *Quarterly Journal of Economics* 118, no. 1 (2003): 1–39; Anthony B. Atkinson, Thomas Piketty, and Emmanuel Saez, "Top Incomes in the Long Run of History," *Journal of Economic Literature* 49, no. 1 (2011): 3–71.

59. Emmanuel Saez, "Striking It Richer: The Evolution of Top Incomes in the United States (updated with 2012 preliminary estimates)," University of California, Berkeley, 3 September 2013, https://eml.berkeley.edu//~saez/saez-UStopincomes-2012.pdf.

60. Thomas Piketty, *Capital in the Twenty-First Century*, trans. Arthur Goldhammer (Cambridge, MA: Belknap Press, 2013).

61. See Alan Krueger, "The Rise and Consequences of Inequality in the United States," Council of Economic Advisers, The White House, 12 January 2012, https://obamawhitehouse.archives.gov/sites/default/files/krueger_cap_speech_final_remarks.pdf;

Dabla-Norris et al., "Causes and Consequences of Income Inequality: A Global Perspective," IMF Staff Discussion Note, SDN/15/13, October 2015, https://www.imf.org/external/pubs/ft/sdn/2015/sdn1513.pdf; Janet Yellen, "Perspectives on Inequality and Opportunity from the Survey of Consumer Finances," speech delivered at the Conference on Economic Opportunity and Inequality, Federal Reserve Bank of Boston, 17 October 2014, https://www.federalreserve.gov/newsevents/speech/yellen20141017a.htm.

62. Jennifer Hunt, Jean-Philippe Garant, Hannah Herman, and David J. Munroe, "Why Don't Women Patent?" NBER working paper no. 17888, National Bureau of Economic Research, March 2012, http://www.nber.org/papers/w17888.pdf.

63. Lisa D. Cook and Yanyan Yang, "The Commercialization Gap in Pink and Black," Michigan State University, mimeo, 2017.