THE DEMOGRAPHICS OF INNOVATION IN THE UNITED STATES

FEBRUARY 2016

**BY ADAMS NAGER,
DAVID HART,
STEPHEN EZELL,
AND ROBERT D. ATKINSON**

ITIF
INFORMATION TECHNOLOGY
& INNOVATION FOUNDATION

The Demographics of Innovation in the United States

BY ADAMS NAGER, DAVID HART, STEPHEN EZELL, AND ROBERT D. ATKINSON | FEBRUARY 2016

The demographics of U.S. innovation are different from the demographics of the country as a whole, and also from the demographics of college-educated Americans—even those with Ph.Ds. in science or engineering.

ABSTRACT

This study provides a detailed portrait of individuals who are driving technological innovation in the United States—including their gender, ethnicity, countries of origin, education, and age—as well as the settings and circumstances in which they are creating their innovations, such as the institution (or institutions) behind the advances, the commercial status of the innovations, and their funding sources. To gather this information, ITIF surveyed more than 900 people who have made meaningful, marketable contributions to technology-intensive industries as award-winning innovators and international patent applicants.

The study finds that immigrants comprise a large and vital component of U.S. innovation, with 35.5 percent of U.S. innovators born outside the United States. Women represent just 12 percent of U.S. innovators, and U.S.-born minorities (including Asian Americans, African Americans, Hispanics, Native Americans, and other ethnicities) represent just 8 percent of U.S.-born innovators. Contrary to popular conceptions about precocious college dropouts with big ideas, U.S. innovators actually tend to be experienced and highly educated—and most hold advanced degrees in the fields of science and technology.

The survey shows that large and very small companies both contribute to innovation: Approximately 60 percent of private-sector innovations originate from businesses with more than 500 employees, and 16 percent originate from firms with fewer than 25 employees. The study also finds that innovation occurs all across the United States, but concentrates in the Northeast, in California, and in areas near national laboratories and other sources of public research spending. Survey respondents cite insufficient funds, market factors, and regulatory constraints as barriers to commercialization.

The report concludes that to boost U.S. innovation, policymakers should broaden and deepen the national pool of STEM talent by improving STEM education and empowering students of all backgrounds to pursue these fields, and by strengthening the pipeline for highly skilled immigrants to work in the United States.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Behind every technological innovation is an individual or a team of individuals responsible for the hard scientific or engineering work. Behind each of these innovators are an education and a set of experiences that impart the requisite knowledge, expertise, and opportunity. These scientists, engineers, entrepreneurs, and managers drive technological progress by creating innovative new products and services that raise incomes and improve quality of life.

But who are these individuals? How old are they? Were they born in the United States or abroad? Are they male or female? What are their races and ethnicities? What kind of education do they have? Identifying the characteristics of the individuals who create successful, meaningful innovation in America can shed important light on how to broaden and deepen the country's pool of potential innovators through STEM education (science, technology, engineering and math), immigration, and overall innovation policies.

This study surveys people who are responsible for some of the most important innovations in America. These include people who have won national awards for their inventions, people who have filed for international, triadic patents for their innovative ideas in three technology areas (information technology, life sciences, and materials sciences), and innovators who have filed triadic patents for large advanced-technology companies. This diverse, yet focused sampling approach enables a broad, yet nuanced examination of individuals driving innovation in the United States.

Immigrants born in Europe or Asia are over five times more likely to have created an innovation in America than the average native-born U.S. citizen.

The demographics of U.S. innovation are different from not only the demographics of the United States as a whole, but also the demographics of college-educated Americans and even those with a Ph.D. in science or engineering.

For example, immigrants comprise a large and vital component of U.S. innovation: 35.5 percent of U.S. innovators were born outside the United States. Another 10 percent of innovators have at least one parent born abroad. Over 17 percent of innovators are not even U.S. citizens, yet are nonetheless making invaluable contributions to U.S. innovation. Immigrants born in Europe or Asia are over five times more likely to have created an innovation in America than the average native-born U.S. citizen. Immigrant innovators are also better educated on average than native-born innovators, with over two-thirds holding doctorates in STEM (science, technology, engineering, and mathematics) subjects. In part, this may be because there is often a selection process for foreign-born innovators where the ones with the most talent (and perhaps most motivation) choose to come to America because of the significant opportunities this country promises for innovators.

Women represent only 12 percent of U.S. innovators. This constitutes a smaller percentage than the female share of undergraduate degree recipients in STEM fields, STEM Ph.D. students, and working scientists and engineers. The average male born in the United States is nine times more likely to contribute to an innovation than the average female. The United States is therefore missing an enormous potential source of innovation. Even at this low level, however, the United States may outperform Europe.

U.S.-born minorities (including Asians, African Americans, Hispanics, Native Americans, and other ethnicities) make up just 8 percent of U.S.-born innovators. However, these groups total 32 percent of the total U.S.-born population. Despite comprising 13 percent of the native-born population of the United States, African Americans comprise just half a percent of U.S.-born innovators. Here, too, is an untapped resource of great promise.

Popular narratives suggest that young, technology-savvy entrepreneurs, some of whom have dropped out of college to found companies in Silicon Valley, drive innovation. However, the median innovator is 47 years of age. Innovators typically have years of work experience and deep knowledge in STEM fields. In addition, innovators in the United States are also, not surprisingly, highly educated, and frequently hold advanced degrees in science and technology fields. Four-fifths of innovators possess at least one advanced degree, and over half have attained a Ph.D. in a STEM subject. Among immigrants, over two-thirds hold Ph.Ds. in STEM fields.

STEM graduates from private undergraduate colleges and universities are more likely to become innovators. However, innovators are more likely to hold graduate degrees from public universities than private ones. While the Massachusetts Institute of Technology (MIT) educated more innovators than any other single graduate university, large public universities, including the University of Illinois at Urbana-Champaign, the University of California at Berkeley, and the University of Texas at Austin followed as the top educators of innovators.

Innovation occurred across the country, but California had the most innovations of any state, with innovations concentrated in the Silicon Valley and the San Francisco Bay Area as well as in San Diego. Controlling for population, the mid-Atlantic and New England states tended to produce the most international patents in life sciences, materials sciences, and information technology, with Massachusetts, Connecticut, Delaware, New Jersey, and Rhode Island leading. Innovations winning awards, meanwhile, clustered around public laboratories and prominent research universities, such as Sandia and Los Alamos National Labs in New Mexico, Oak Ridge National Lab in Tennessee, and universities in Berkeley, California, and Cambridge, Massachusetts.

In addition to exploring the demography of innovation, this study sheds light on the innovations themselves and the organizations that produce them. The sample of meaningful and marketable innovations includes both fully commercialized innovations as well as innovations still in development. Over two-fifths of innovations in the sample are available on the market, and one-quarter have generated over $25 million in total revenue. Among innovations not commercialized, innovators cite insufficient funds, market factors, and regulatory constraints as barriers that slow or prevent commercialization.

Among private firms that produce groundbreaking innovations, both very small and large companies contribute to innovation. Approximately 60 percent of private-sector innovations originate from businesses with more than 500 employees, and 16 percent originate from firms with fewer than 25 employees. Moreover, reinforcing the critical role of the federal government in supporting innovation, over half of this latter group received assistance from public sources, including grants from the Small Business Innovation Research (SBIR) program, the Departments of Defense and Energy, and the National Institutes of Health (NIH).

The remainder of this report reviews the existing literature surrounding innovation demographics, reports the survey's methodology, and then presents the survey's findings.

Finally, we briefly discuss policy ideas to strengthen U.S. innovation and empower more individuals to become innovators.

LITERATURE REVIEW

Before discussing the research methodology and findings, it is worth reviewing related research on the demography of innovation. A large literature has undertaken investigating the characteristics that are associated with successful innovation. However, the existing literature has pervasive limitations. Many of the following papers examine only a single aspect or characteristic of innovator demographics. Papers that do examine demographics as a whole predominately look at individuals with the potential to innovate instead of examining individuals who have already successfully innovated. Additionally, our focus on the U.S. context is unique.

Age

Of entrepreneurs educated at MIT starting businesses, only 4 percent founded their companies before the age of 23, and only 13 percent do so within five years of graduating.

Some recent studies help establish the average age for innovation. Because the methodologies of these studies differ, they offer various insights into the age when individuals develop innovations. A survey of 1,919 U.S. patent holders by Walsh and Nagaoka in 2008 establishes an age profile of U.S. inventors. Drawing from a range of patent categories, they find that American inventors average 47 years of age, with roughly equal proportions of inventors below the age of 40 and above the age of 50.[1] Most inventors were in their early thirties at the time of their first patent filing. This study provides the most relevant baseline to compare our study to since, due to the creeping increase in age following changing demographics, earlier assessments of innovator demographics may prove less useful for our purposes.

Studying the changes in innovator age over time, Jones examines a dataset of 547 Nobel Prize winners and 286 inventors drawn from technological almanacs. He finds that from 1965 to 1998, the average age of innovators at the time of their great invention was about 40 years old.[2] Furthermore, he concludes that great inventors in the latter half of the 20th century created their crowning achievements an average of eight years later than inventors in the earlier half of the century. Jones attributes this increase in age to a decline in innovative output of younger innovators rather than the demographic shift arising out of an aging population. Jones estimated a 30-percent decrease in innovation potential over the 20th century from the later onset of inventions.

As life expectancies increase, inventors have more time to produce inventions. However, many hypothesize that because of the growing complexity of science and technology innovations take more time and require higher levels of specialized knowledge. For instance, in areas such as pharmaceuticals, researchers require about a decade to develop a successful commercial drug, and almost all researchers hold Ph.Ds.[3]

In addition to the possibility of the population's increasing age influencing the average inventor age, the accumulated pool of scientific knowledge gets progressively larger over time, and innovators may have to spend a longer time in a certain field to develop the specialized knowledge required to create innovations. In a study of U.S. patent filers, however, Jones finds that "there is at most only a weak relationship between the amount of knowledge underlying a patent and the age at first innovation."[4] Thus, his findings suggest that factors outside of, and perhaps in addition to, accumulated knowledge stimulate innovation generation.

Research has also shown that cultural factors may affect an innovator's age of invention. Walsh and Nagaoka's study show that U.S. innovators were on average seven years older than Japanese innovators. Furthermore, U.S. innovators tend to move between firms early in their careers, while Japanese innovators are more likely to be mobile later in their careers. Although U.S. innovators start innovating at a later age compared to Japanese innovators, U.S. innovators continue to innovate into their later years, while Japanese innovators generally stop innovating, likely a result of earlier retirement rates in Japan.[5]

These results point to innovation concentrating in slightly older populations. This runs counter to the popular narrative that U.S. innovation is driven by young entrepreneurs. Of entrepreneurs educated at MIT starting businesses, only 4 percent founded their companies before the age of 23, and only 13 percent do so within five years of graduating.[6]

Gender

The gender gap in STEM fields is widely acknowledged.[7] Although females make up almost half of the U.S. workforce, including the college-educated workforce, they account for just 24 percent of workers in STEM jobs.[8]

Some studies have examined gender in innovation. In their study of Swedish patent holders, Jung and Ejermo found that, although the share of women holding patents increased from 2.4 percent in 1985 to 9.1 percent in 2007, this rate of increase was slower than the rate of increase of females holding Ph.Ds. in science, technology, and medicine fields.[9] Giuri et al. found that female participation in European innovation was "remarkably low," with females representing just 2.8 percent of inventors in their sample of 9,017 patents granted by the European Patent Office between 1993 and 1997.[10] By looking across countries within the European Union and across industry fields, they find that the gender disparity was the least pronounced in chemicals and pharmaceuticals (7.4 percent female) and the most pronounced in mechanical engineering (1.1 percent female). Furthermore, because of a reduced share of women along STEM career paths, the gender gap is more pronounced in positions requiring greater experience.[11]

Women are also underrepresented among high-growth entrepreneurs. In 2014, female-founded or co-founded companies accounted for just 17 percent of U.S. angel, seed, or other early venture capital investment. While this represents significant progress from 2000, when female-founded and co-founded companies received just 5.7 percent of capital investment, women in the United States are still substantially less likely to found high-tech startups with high growth potential and less likely to receive investment dollars than men.[12] Additionally, women represented only 14.9 percent of individuals receiving late-stage Small Business Innovation Research grants from the National Institutes of Health.[13]

The finals of the 2015 DARPA Robotics Challenge in Pomona, California, also saw large imbalances in gender among competitors.[14] Of the 24 teams competing, 11 were composed completely of men. Only 23 of the 444 contestants, or 5.2 percent, were women.

Nationality and Immigration Status

Scholarly studies have consistently provided evidence of the positive effects of high-skill immigration on U.S. innovation. Though scholarly work on immigration and entrepreneurship in the United States is widespread, few papers specifically explore the immigration status and country of origin for leading innovators.

Hart, Acs, and Tracy studied the role of immigrant entrepreneurs in rapidly growing high-impact and high-tech firms in the United States, finding that 16 percent of companies had at least one immigrant founder.[15] Immigrants from India and the United Kingdom accounted for the largest share of foreign-born entrepreneurs, at 16 percent and 10 percent, respectively. These immigrants were likely to have lived in the United States for over two decades, and two-thirds had undergraduate degrees from U.S. universities, reinforcing the need for policies to make it easier for foreign STEM students to stay in the United States.[16]

Other studies estimating the percentage of innovative companies with at least one foreign-born founder have found figures ranging from 16 to 26 percent.[17] Kerr reports that roughly one-quarter of U.S. innovators, as well as roughly one-quarter of entrepreneurs in successful high-tech firms, are immigrants, and that immigrant innovators are on average better educated than native-born innovators.[18] However, the number of immigrants founding high-tech startups seems to be in decline, despite more foreign-born workers employed in high-tech sectors.[19]

Scholarly studies have consistently provided evidence of the positive effects of high-skill immigration on U.S. innovation.

In another study, Hart found that foreign-born founders of companies were more likely than their White, U.S.-born counterparts to collaborate with other foreign-born individuals, minorities, or women.[20] Though the study found evidence that a nationally diverse team may increase firm performance, the results were not statistically significant. In addition, immigrant-founded firms were twice as likely to have a strategic relationship with a foreign firm.[21]

Walsh and Nagaoka found that 30 percent of patent holders in the United States were born abroad. The top five countries of birth for patent holders were China (4.7 percent), India (3.7 percent), the United Kingdom (2.7 percent), Taiwan (2.4 percent), and Canada (1.8 percent).[22] Their analysis also revealed that foreign-born patent filers produced inventions of higher value compared with similarly educated, native-born patent filers.[23] The authors conclude that foreign-born inventors are highly innovative due to the double selection process they face—self-selection to bring their talent to a foreign country and selection through U.S. immigration's screening process.[24]

Similarly, in studying immigrants through the 2003 National Survey of College Graduates, Hunt finds that economic value contributed to the U.S. economy is dependent on visa type. Hunt ranks contributions by postdoctoral fellows and medical residents as the most valuable, followed by graduate students, temporary work visa holders, college students, other students/trainees, legal permanent residents, dependents of temporary visa holders, and other temporary visa holders, in that order.[25] This echoes the findings of Walsh and Nagaoka's that highly educated immigrants provide much higher value added than other less-educated immigrants, and equally educated native populations.

According to Hunt, "Immigrants who originally entered the United States on temporary work visas or on student/trainee visas outperform native college graduates in wages, patenting, commercializing and licensing patents and authoring books or papers for publication or presentation at major conferences."[26] This suggests a higher average level of productivity for immigrant innovators compared with native innovators. Moreover, Peri, Shih, and Sparber find that H-1B visa STEM workers raise wages for native college graduates, suggesting a positive effect on total factor productivity as more and better foreign innovators grow the "innovation pie."[27]

Immigrants are particularly inclined to leverage their technical knowledge from master's and doctoral degrees to create new, successful businesses.

Within immigrant populations in innovation industries, demographic differences stand out. In a study of Swedish foreign-born inventors, Zheng and Ejermo found that females of Asian origin have a larger gender share than females from the European Union, at 17.4 percent and 8.3 percent respectively.[28] Additionally, inventors from Oceania (36 years) were on average younger than inventors from Nordic countries (48 years).[29]

Ethnicity

There has been significantly less research on race and innovation. However, research on the composition and leadership of teams receiving public research grants tend to show limited participation by minorities. A study of late-stage Small Business Innovation Research grants given by the National Institutes of Health, a $750 million per year funding program, found that only 2 percent of grants went to teams with Hispanics listed as the principal investigator and 0.3 percent of grants went to teams with Blacks as the principal investigator. Asians represented 6.8 percent of principal investigators.[30]

Education

As fields of knowledge expand due to greater levels of basic research, inventors may require more specialized knowledge to produce innovations. Often, innovators acquire specialized knowledge through the attainment of tertiary degrees in scientific fields. Walsh and Nagoaka find that 46 percent of U.S. inventors have a Ph.D., compared with 13 percent in Japan.[31] Jung and Ejermo find that 30 percent of Swedish patent filers hold Ph.Ds.[32] A Japanese study, with a sample of 1,731 innovators, found that innovators with Ph.Ds. have a higher level of productivity and work longer as innovators than those with less education, controlling for years spent on education. A European Union study, through a sample of 9,017 patents, found that high levels of education positively affect the quantity of patents an inventor produces, and indirectly increases the maximum quality of the inventor's patents.[33]

In the United States, immigrants are more likely than native-born individuals with similar levels of education to create a successful startup.[34] Roughly 55 percent of foreign-born startup founders hold a master's degree or doctorate, and are twice as likely as U.S.-born founders to hold a doctorate. In contrast, for high-impact, high-tech firms, 9.6 percent of U.S.-born founders have a high-school degree or less as their highest educational qualification, twice that of foreign-born founders.[35] This shows that immigrants are particularly inclined to leverage their technical knowledge from master's and doctoral degrees to create new, successful businesses.

METHODOLOGY

While there is an existing literature on innovation and immigrant demographics, our research represents, to our knowledge, a novel contribution to the field of demographic studies. Our approach begins with a sample of high-value innovations and then identifies innovators behind them.

Many preceding papers pertain to the characteristics and backgrounds of academics, scientists, entrepreneurs, and researchers. These approaches address and identify people who have high innovation potential, but fail to identify who actually succeeds at creating innovations. For example, data on educational attainment and the native countries of student immigrants is a valuable source of information for tracking who goes into academia or other types of research. The SESTAT (Scientists and Engineers Statistical Data System) database, academic publishing data, and patent data illustrate with high clarity the demographics of basic researchers in the United States.[36] The data is ineffective, however, in describing outcomes. Specifically, such data cannot identify which of these students go on to become the most productive innovators. Surveys specifically looking at academics, such as those developed by Walsh, Huang, and No, do not focus on the vast amount of innovation that goes on outside of universities and public labs that has a direct impact on the economy.[37]

Rather than using entrepreneurship, advanced degrees, or patents filed as metrics to approximate the creation of successful, commercial inventions, we identify meaningful and marketable innovations and then study the people behind them.

We also dig deeper than simple invention. Invention is the creation of something new that has some utility, while innovations add the criteria that the "something new" can be marketed successfully.[38] While not every innovation in our sample has reached full commercial status, our samples pull from innovations with clear market applications and value, as expressed by either the nature of the company filing the patent, the patent's need for international protection, or the fact that it has won an award for which market readiness is a prerequisite. Our approach is more akin to the methodology behind Hart and Acs' paper on immigration in entrepreneurship, which began by identifying "high-impact, high-tech" companies and then examining the entrepreneurs who founded them.[39]

This approach is unique in the literature and can produce a better understanding of who in America actually innovates.

Five Samples for Measuring Innovation

The Demographics of Innovation project seeks to identify, contact, and survey individuals who have created valuable innovations in terms of knowledge creation and economic impact. There is no single source that covers all aspects of what we attempt to measure. As a result, the study focuses on five distinct samples that together provide an in-depth analysis of individuals creating top innovations.

The first sample is comprised of individuals recognized for groundbreaking innovations by *R&D Magazine*'s annual R&D 100 Awards. These awards honor innovators behind the most innovative technologies introduced to the market in a given year.[40] For example, in 2015, some of the winners included Continuous Active-Source Seismic monitoring, created by the Lawrence Berkeley National Laboratory; the Toyota fuel cell system; a 3D printing software package developed by Oak Ridge National Laboratory and Alpha STAR corporation; and a speech therapy device for individuals with Parkinson's disease created by a medical device startup called SpeechVive.[41]

The other four samples come from triadic patents likely to have significant economic impact. Triadic patents are filed internationally in the United States, Europe, and Japan in order to guarantee intellectual property protection worldwide. Three of the four triadic patent samples pull from technology- and knowledge-intensive fields of innovation: life sciences, materials sciences, and information technology.[42] The fourth surveys the innovators behind triadic patents filed by large advanced technology companies to discover who drives important innovation in these successful firms.

Table 1: Characteristics of the Five Samples[43]

Sample	Innovations in Sample	Years	Innovators per Innovation
R&D 100 Awards	100 per year	2011, 2012, 2013, 2014	8.4
Triadic Patents- Life Sciences	100 per year	2011, 2012, 2013, 2014	2.9
Triadic Patents- Materials Sciences	100 per year	2011, 2012, 2013, 2014	3.8
Triadic Patents- Information Technology	100 per year	2011, 2012, 2013, 2014	3
Triadic Patents- Large Tech Companies	1,064	2014-2015	2.4
Total	2,651	2011-2015	3.7

Because more than one innovator frequently appears on each triadic patent or R&D 100 Award, the total number of innovators in our sample exceeds the total number of innovations. In total, the Demographics of Innovation sample comprises 9,757 innovators, who together created 2,651 distinct, leading innovations between 2011 and 2015.

The number of innovators on triadic patents is fairly consistent among the four triadic patent samples, ranging from 2.4 innovators per large tech company patent to 3.8 innovators per materials sciences patent. Teams on R&D 100 Awards were much larger, with an average of 8.4 innovators per innovation.

There are, of course, biases in each of our samples. Rather than attempt to create a completely unbiased sample, we attempt to find samples biased toward high-level innovations, accepting the various biases associated with those samples. The unique biases in each sample both contrast and complement each other. This helps create a complete and diverse view of the individuals behind top innovations across industries, institution types, and technology areas. While this approach precludes large regression models that could attempt to determine causal direction, it allows us to apply our data to those who have attained success, observing characteristics of innovators and innovations in these five samples. Descriptive data yield simple, direct characterizations of top innovators. These simpler conclusions are clear, powerful tools for conveying information about the implications of the demography of innovation to policymakers.

R&D 100 Awards

The R&D 100 Award is an annual award given through *R&D Magazine* honoring 100 leading innovations reaching the marketplace that result from R&D in advanced industries. R&D 100 Award-winning innovations are among the most cutting edge and influential technologies introduced over the past year, have an outsized impact on markets, and contribute heavily to future innovation. The awards carry considerable prestige within the community of R&D professionals and are comparable to the Oscars in the film industry. Organizations or innovators nominate their own innovations for the award, leading to a self-selected nominee pool. Juries that include representatives from business, government, and universities initially evaluate all entries. After considering the outside juries' votes, the magazine's editors decide on the final list of awards.

Awards are sorted into technological categories that include mechanical devices, materials, information technology, electrical, analytical, processes, and software. This provides a small sampling of highly regarded innovations from each of these scientific disciplines. However, an innovation need not fit neatly into one of these categories to be considered, nor are categories given quotas.

The innovators who contributed to innovations winning R&D 100 Awards are listed with their innovation on the R&D 100 Awards website. Each innovator listed on a winning innovation from 2011 to 2014 (whose location at the time of innovation was inside the United States) is included in the sample.[44]

The organizations that apply for consideration for R&D 100 Awards influence the composition of the sample. *R&D Magazine* does not release data on the number of applicants for its awards per year nor the characteristics of non-winning applications. However, the prestige of the award is such that large companies, startups, government labs, and university teams alike have incentives to apply. The judges have no parameters or quotas for what type of innovations or innovation organizations to select, yet this does not firmly rule out the possibility of selection biases based on organization type or field of science.

R&D 100 Awards do have a number of biases, though for our purposes these biases are a feature rather than a flaw. The R&D 100 Awards focus on pure commercial applications and recognize those who transform basic and applied research into marketed, commercialized products, thus understating the contribution of basic R&D.[45] We see this in the responses to questions concerning the commercialization status of R&D 100 Awards–49 percent of R&D 100 Award-winning innovators deemed their products to be fully commercialized, while another 27 percent said their innovations were in the "prototype" phase. Only 4 percent reported that their innovations were incomplete and still undergoing research. This suggests R&D 100 Award-winning innovations are on average closer to market than are innovations in our triadic patent samples.

R&D 100 Award innovations are also biased against those in military technology, a mainstay of federal research funding. Still, R&D 100 Awards have a much higher rate of government funding representation, with one-half derived from either government research laboratories or universities. By contrast, among subject field patents that total is only around 11 percent.

The teams of innovators listed on R&D 100 Awards that comprised the sample are much larger than those typically found listed on triadic patents (8.4 innovators compared with between 2.4 and 3.8 innovators). The difference could be due to the larger complexity and scope of innovations winning the R&D 100 Awards. However, the more likely reason is that R&D 100 Award-winning innovations are more likely to list more junior members of the team as contributing innovators. By contrast, triadic patents only include individuals who fit the legal definition of "inventors." R&D 100 Awards, in which there is little cost to recognizing additional team members and no legal status concerning ownership conferred to listed innovators, naturally report more contributors.

More expensive and harder to secure than typical domestic patents, triadic patents typically represent valuable innovations with high commercialization potential that require global protection.

Triadic Patents

Triadic patents are filed jointly in the United States, the European Union, and Japan. This joint application process requires payment to all three patent offices, and forms what is referred to as a "family" of patents. More expensive and harder to secure than typical domestic patents, triadic patents typically represent valuable innovations with high commercialization potential that require global protection. Because of their high value, triadic patents are a better metric of innovation than regular U.S. patents, which are easier to acquire and tend to include less valuable, narrower, and less marketable innovations. Previous studies have demonstrated that the cost of triadic patents serves as an effective obstacle that excludes low-value innovations from the sample.[46] Similar to the inclusion of R&D 100 Awards, examining triadic patents in technology-intensive industries and top companies permits insight into ideas that actually go into production compared with innovations that are patented but may never be commercialized.

Of the triadic patent sample, we seek to identify triadic patent applications from technology-intensive industries that invest significant amounts of R&D and will likely have large commercial applications. The first way we accomplish this is by sampling from triadic patents filed in technology-intensive fields. We elected to examine three high-tech categories: materials sciences, life sciences, and information technology. We randomly sample 100 innovations from each of these categories for the years 2011, 2012, 2013, and 2014, for a total of 400 innovations in each of the three categories. We build our sample based on the names of the inventors from the randomly selected triadic patents.

In addition, we identified lists of patents filed by a small number of technology companies who made prolific triadic patent filings in 2014 and 2015. These are all large, R&D-intensive technology companies that have proven successful in innovating and bringing new technologies to market. Based on the size and innovation track records of these firms, these patents have the potential to contribute to innovations with large market impacts, in part because the innovations are considered to be worth enough to patent in three regions and because these companies have global market access. Titled large, advanced technology patents, we refer to this sample from here on as "large tech companies." As with all data on innovators and firms collected for this paper, the companies we sample from remain anonymous.

Data Collection

With our samples identified, our research team attempted to find email addresses for each innovator. As email addresses and contact information are not made public by either the patent office or *R&D Magazine*, researchers made best-faith efforts to find contact information for each innovator in the sample using publicly available listings online, including Google searches of innovator names and employers, where publicly listed. For a more detailed description of the search methodology, see Appendix D. The large tech company triadic patent sample plugs innovator names into email formats commonly used by each company, a method described in detail in Appendix C.

Through this method, we were able to find contact information for 55.8 percent of the population for R&D 100 Awards and life sciences, materials sciences, and information technology triadic patents (referred to together as "subject field patents"), along with a guess for every innovator in the large tech company sample. The availability of contact information was for the most part random, but did follow a few patterns that introduce biases into the subset of the sample that we were successfully able to reach with our survey. The biases related to firm type and the seniority level of each innovator are described in depth below.

Table 2: Sample by Size and Success Rate[47]

Sample	Innovators in Sample	Innovators Emailed	Success Rate
2014 Subject Field Patents	934	540	58%
2013 Subject Field Patents	981	472	48%
2012 Subject Field Patents	969	526	54%
2011 Subject Field Patents	903	456	50%
2014 R&D Awards	714	514	72%
2013 R&D Awards	805	445	55%
2012 R&D Awards	855	487	57%
2011 R&D Awards	1,051	414	39%

In some cases, emails represent best guesses at email addresses using known formats or other information. As a result, roughly 10 percent of the emails we sent were undeliverable. For assessing biases, nonfunctional emails are regarded as being equivalent to having no email at all, and are not included in the totals presented in Table 2. We have no reason to believe that there is a bias to which undeliverable emails are reported as undeliverable, or that a significant number of the emails that do not get marked as undeliverable were in fact sent to incorrect addresses.

Response Rates

R&D 100 Awards had a response rate of 19.4 percent. As life sciences, materials sciences, and information technology patent surveys were emailed together by year, their response rates are reported together, under "subject field patents." These subject field patents had a combined response rate of 17.3 percent. Large tech company patent surveys were emailed separately and not broken down by year. Moreover, the large tech company mailings did not record emails marked as undeliverable, so response rates reflect the success rate for the entire sample. Innovators for whom emails were sent and immediately returned marked "undeliverable" by our email client are excluded from the sample of Innovators Emailed. These response rates are low, but given the nature of information requested and the method of collection, they match expectations. Response rates ranging from 15 to 25 percent are considered standard and successful for this type of survey.[48]

Table 3: Response Rate, by Sample[49]

Sample	Innovators Emailed	Responses	Response Rate
2014 Subject Field Patents	540	89	16.5%
2013 Subject Field Patents	472	85	18.0%
2012 Subject Field Patents	526	92	17.5%
2011 Subject Field Patents	456	78	17.1%
2014 R&D Awards	514	97	18.9%
2013 R&D Awards	445	106	23.8%
2012 R&D Awards	487	75	15.4%
2011 R&D Awards	414	82	19.8%
Large Tech Companies	2,564	219	8.5%
Subject Field Patents Subtotal	1,994	344	17.3%
R&D 100 Awards Subtotal	1,860	360	19.4%
Total	6,418	923	14.4%

The large tech company triadic patent sample predictably had a much lower response rate, as discussed above. We believe that the overall response rate of individuals receiving emails was not significantly different, but that fewer emails made it to their destinations. Unlike other samples, we contacted every individual in the sample using email addresses generated from email formats associated with the tech company. Though we know many emails did not reach their destinations, undeliverable emails for large tech companies are not recorded. (See Appendix C.)

Some respondents chose to reply to the sample anonymously. Because we did not track based on IP address to respect privacy, we were unable to match respondents with their respective innovations. Overall, 81.6 percent of respondents gave their full name. However, for the other 18.4 percent, we were only able to tell which sample and data year to which they belonged. For triadic patents in materials sciences, life sciences, and information technology, anonymous responses could not be sorted into a technology field, so these responses are included in calculations of total averages for subject field patents but not in any field-based sample. We are also unable to match anonymous responses to innovations, meaning these responses are excluded from analysis based upon the innovations, instead of innovators. However, we have no reason to believe that responses that report names and those that did not bear any substantive difference, nor do we have reason to doubt the quality of anonymous responses.[50]

Response Bias

Surveys tend to have low response rates, typically in the range of 15 to 25 percent of the sample.[51] Collecting emails by hand, which has a success rate of only 50 to 60 percent, magnifies the low response rate. As a result, there is the possibility that the innovators responding to the survey do not accurately represent the sample as a whole. Our methodology must consider both for response bias—created by certain types of innovators being more likely than others to respond when contacted, and for selection bias—created by certain types of innovators being easier to contact.

In our research, two types of systematic selection biases were observed, based around differences in the ease of collecting email addresses based on seniority of researcher and type of research organization.

Mid-career researchers are the easiest to find contact information for (unless they changed jobs recently). Junior researchers, including undergraduate and junior graduate research assistants, have lower success rates since they tend to be temporary team members. The most senior team members, who include CEOs, company founders, and senior researchers, list their information publicly less frequently, and thus have lower contact success rates.

Universities and public research institutions typically make researcher email addresses readily available online. Addresses for smaller private organizations (such as startup companies) are easy to find as well. Large companies, especially ones that are not primarily research-based, will usually not make individual contact information available to the public. These addresses can only be found online if the researchers happen to list their contact information in conference proceedings, papers, or similar documents. For innovators for whom we could not find email addresses, we often had to guess addresses based on how companies format their email addresses.[52] This bias in most samples limits the representation of very large firms. The large tech company sample tries to correct this imbalance and helps to ensure that these contributions are captured.

In addition, the farther removed an innovator is from the time of the innovation, the more likely that the innovator has moved on from her employer or changed roles. As the name of the company is a useful tool in identifying innovators and finding contact information, we had more success contacting 2014 R&D 100 Award winners and triadic patent filers than we did for innovators in 2011.

While selection biases were readily observable during the email collection process, response biases were harder to diagnose. We expected significantly lower response rates among innovators in the 2011 data year than innovators from the 2014 data year; however, there was no such pattern.

Comparing Respondents to the Overall Sample

Understanding the skews and biases in the five samples can help identify the types of innovations and innovators these results illustrate. Mostly, these skews, while serious, are not concerning. Frequently, the samples are biased toward innovations that have reached the market or that are more technology-intensive, which we regard as a positive.

What we were concerned about, however, was skews in the makeup of innovators among ethnic and gender lines. However, we are able to make strong guesses on gender and ethnicity for all innovators in the sample based on the linguistic structure of their first and last names. We used an onomastic algorithm, the NamSor Gender and Country of Origin API tool, which uses observable trends in naming to predict an individual's gender and country of origin.

By comparing the algorithm's aggregated guesses for different subsets of the sample, we can determine whether these subsets are comparable. Primarily, we were interested in the subset of innovators who responded to the sample, the subset for which we were able to find contact information, and the total sample. Using these subsets, we ran tests to see if the basic gender and ethnic makeup of the responding innovators was significantly different from the total sample, which would imply bias. Comparing the total sample to the subset of innovators for whom we found email addresses differentiates between biases in finding email addresses and biases in varying response rates along gender or ethnic lines. (See Appendix E.)

The NamSor API tool guesses country of origin based upon name.[53] However, as many countries have similar linguistic traditions, we chose to group guesses by language family. For instance, the Chinese language family includes guesses for China, Hong Kong, Mongolia, and Taiwan.

Statistical evidence suggests that the overall ethnic distribution of the entire sample is not statistically different from the subset of responding innovators.[54] As a total sample, guesses for country of origin were not significantly different for any subset.

We did, however, observe a statistically significant underrepresentation of responding innovators predicted to be in the Chinese language family when comparing respondents with the entire sample and with the portion of the sample that was successfully contacted. This means that innovators with Chinese heritage had a much lower response rate than expected.[55] The NamSor API guessed that 9.8 percent of the total sample population (and 9.7 percent of the sample for which we found emails) was of Chinese heritage. In comparison, the NamSor API guessed that only 6.6 percent of the population of responding innovators was of Chinese heritage. This result shows that while the total distribution of guessed country of origin for responding innovators is a good fit for the guessed country of origin for the entire sample, the NamSor estimate suggests that Chinese names are 50 percent less common for innovators who responded as opposed to innovators who did not, indicating a significant response bias that underrepresents names guessed to be of Chinese origin.

Innovators in the Indic language family group, which includes India, Pakistan, Bangladesh, and Sri Lanka, were significantly underrepresented among emails, suggesting that we had a harder time locating email addresses for these innovators, but also that those successfully contacted replied at above average rates. This observation does not disturb our overall ethnicity findings.[56] The NamSor API guessed that 9.1 percent of the total sample population was of Indic descent, compared with 7.4 percent of the sample for which we found emails, and 8.1 percent of the population of responding innovators.

Table 4: Estimated Percentage of Names by Sample Subset and Language Family

NamSor API Estimates	Indic Language Family	Chinese Language Family
Total Innovators in Sample	9.1%	9.8%
Innovators with Email Addresses	7.4%	9.7%
Responding Innovators	8.1%	6.6%

The NamSor API Gender tool allows us to approximate the total number of men and women in the sample (described in Appendix E). The API tool uses macro-patterns to estimate the probability that an innovator is male or female based on the name. Using this tool, we compared the API's estimates on gender for the subset of the sample that responded to the estimates for the entire sample.

The results indicate that the responding innovator group was not statistically different from the total sample population.[57] The result supports our assumption that the subset of responding innovators approximates the entire sample, and that selection and response biases do not significantly distort the responding sample.

Survey Methodology

Once we collected addresses for the sample, we sent innovators emails asking them to complete a 10-minute survey. We sent these emails four times over the course of a month, requesting the recipient's participation. Questions pertained to each innovator's demographic profile, including country of birth, parent's country of birth, ethnicity, gender, age, and immigration status. Education questions sought to identify degree, subject matter, and institution for each tertiary degree the innovator had completed. We also asked questions regarding the innovation, including questions about the size and age of the filing company, the current commercialization status of the innovation, barriers to commercializing the innovation, and total profits to this point from the innovation. We also asked innovators whether their innovation was the result of collaboration with another institution, and where the innovation occurred. Appendix F presents the full survey instrument.

FINDINGS

This section describes our findings in the following demographic categories: gender, ethnicity and country of origin, education, and age. We also explore details pertaining to the innovation, such as the institution (or institutions) behind the innovation, its commercial status, and its funding sources. Each category presents descriptive statistics based on our five samples: R&D 100 Award winners, triadic patent filers in life sciences fields, triadic patent filers in materials sciences fields, triadic patent filers in information technology fields, and triadic patent filers from large tech companies.

The data presented below, except where otherwise stated, represents simply the number of responding innovators or the percentage of innovators among those who responded to the relevant survey question. We do not attempt to identify or assign causal relationships or run multi-variate regressions requiring stringent assumptions on sample size and the absence of bias, but instead observe correlations within the data, indicate where results are statistically significant, examine differences among the five samples, and compare survey results to data describing trends among the entire U.S. population, immigrants to the United States, Ph.D.-holders, and other groups to examine differences between our sample and the U.S. population at large.

Instead of worrying about whether immigrants crowd out native born, we should focus on increasing the total stock of individuals in the United States with the skills to innovate.

This study is also unable to determine whether certain groups are "crowded out" of innovation, or to what degree this may be occurring. However, we do not hypothesize that any specific group displaces innovation opportunities from another. There is no fixed level of innovation in the United States; opportunities to innovate are unbounded. Instead of worrying about whether immigrants crowd out native born, we should focus on increasing the total stock of individuals in the United States with the skills to innovate.

Gender

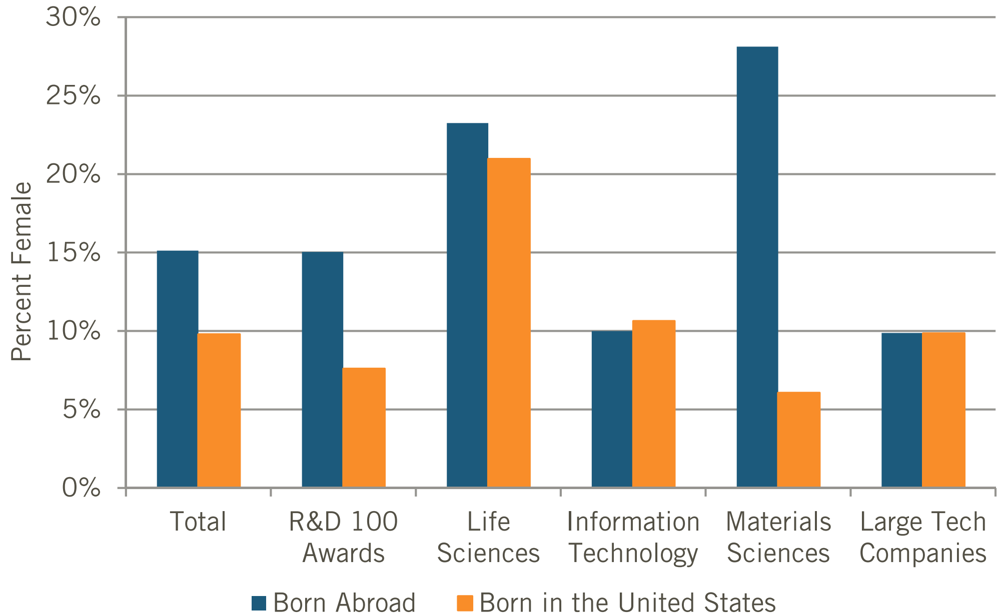
Females are conspicuously underrepresented in these groups of innovators, with over 7.5 male respondents for every female respondent.

Table 5: Male and Female Innovators, by Sample

Gender by Sample	Males	Females
Total	88.3%	11.7%
R&D 100 Awards	89.8%	10.2%
Life Sciences	78.5%	21.5%
Information Technology	89.7%	10.3%
Materials Sciences	86.9%	13.1%
Large Tech Companies	90.3%	9.7%

Among samples, the percentage of women ranges from 21.5 percent of life science innovators to 9.7 percent in large tech companies' triadic patent filers. The higher (but still low) rates of female respondents in the life sciences may relate to higher rates of female scholarship in life science fields: Over half of biology doctorates are awarded to women. The lower female participation rate among large tech companies may stem directly from the lack of women in engineering fields, as engineers are heavily represented in the large tech companies' sample. Similarly, lower female participation rates in information technology patents and R&D 100 Awards illustrates different gender concentrations in different scientific fields.

Figure 1: Percentage of Females Among Innovators Born in the United States and Among Innovators Born Abroad, by Sample



The higher (but still low) rates of female respondents in the life sciences may relate to higher rates of female scholarship in life science fields.

Immigrants also showed heavy gender skews, but these proved to be significantly smaller than among innovators born in the United States. Of respondents, only 9.8 percent of U.S.-born innovators are female, compared with 15.1 percent of foreign-born innovators. The disparity was especially prevalent in the materials science sample, where females constituted a mere 6.1 percent of U.S.-born innovators compared with 28.1 percent of foreign-born innovators. Additionally, among R&D 100 Award winners, females were almost twice as prevalent among innovators born outside of the United States, representing 15 percent of innovators born abroad and only 7.6 percent of innovators born in the United States. The proportion of females innovating through life sciences patents, information technology patents, and large tech company patents, meanwhile, are similar regardless of country of birth.

It is not clear why females are better represented among foreign-born innovators than among U.S.-born innovators. One reason may be that, relative to many nations, women with the potential to innovate may have more professional opportunities in the United States and less sex-based bias than in other nations, particularly in developing nations. In this sense, highly educated women born abroad may have greater motivation to move to the United States to take advantage of the greater opportunities in the United States.

Table 6: Birthplace of Innovators, by Gender

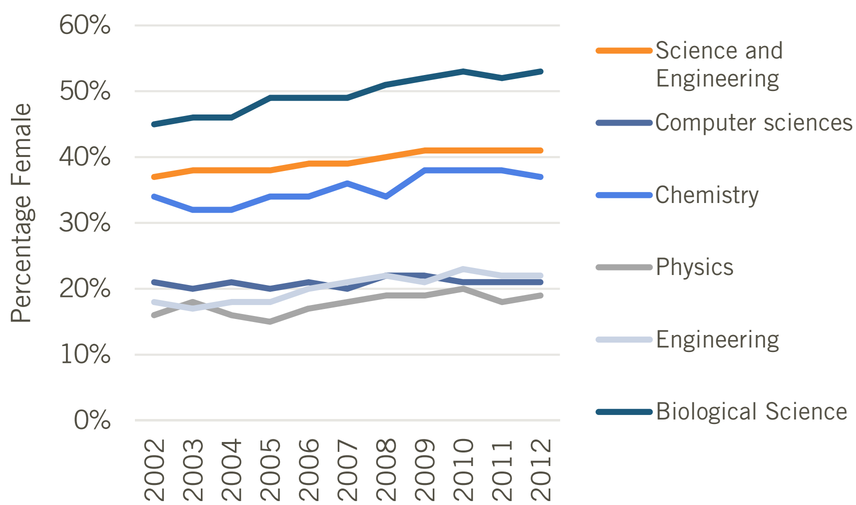
Birthplace	Males	Females	Percentage Female
United States	516	56	9.8%
Outside United States, Total	290	50	14.7%
Europe	94	17	15.3%
China	44	10	18.5%
India	62	5	7.5%
Elsewhere	88	18	17.0%

Chinese females represented 10 out of 54, or 18.5 percent, of total Chinese respondents, significantly higher than the percentage of U.S.-born innovators despite the small sample size.[58] Similarly, 15.3 percent of innovators from Europe were female, again a significantly higher percentage than the share of female innovators in the United States. On the other hand, only 5 out of 67 innovators who emigrated from India were female.

Contributing to low rates of female innovation are low enrollment numbers for women in STEM doctorate programs.

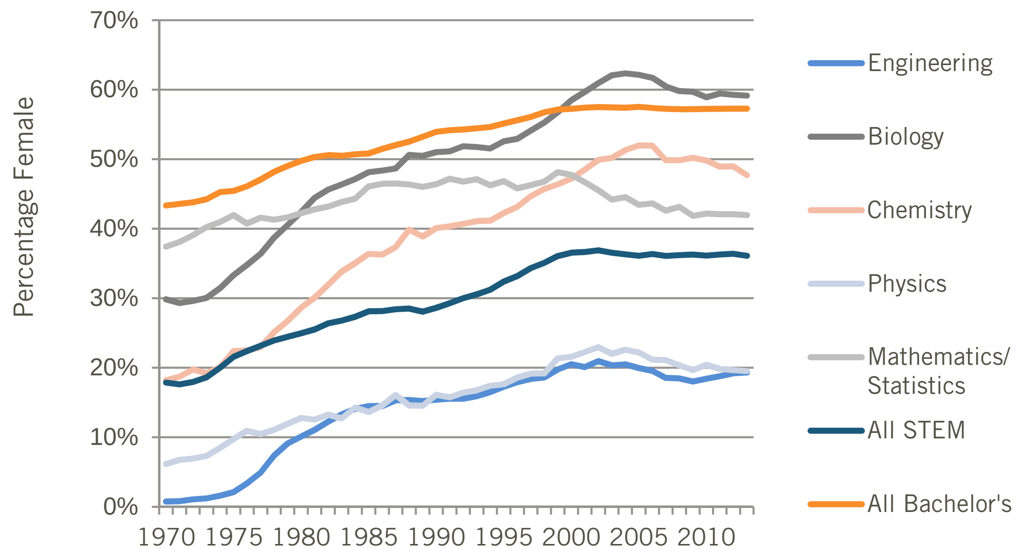
Contributing to low rates of female innovation are low enrollment numbers for women in STEM doctorate programs. According to data from the National Science Foundation (NSF), only 37 percent of chemistry Ph.D. recipients, 22 percent of engineering Ph.D. recipients, and 21 percent of computer science Ph.D. recipients are female. (Figure 3) However, even in these fields, Ph.D. enrollment rates among women are significantly higher today than in 2002. Within their respective fields, low graduation numbers for women contribute to their low involvement in innovation. The gap for total doctorates, by comparison, is nonexistent. In fact, in 2013, women received the majority of Ph.Ds. (despite earning just 11 percent of all doctorates in 1970) as well as 60 percent of bachelor's and 57 percent of master's degrees.[59]

Figure 2: Percentage of Ph.D. Degrees Earned by Women by Field, 2002 to 2012[60]



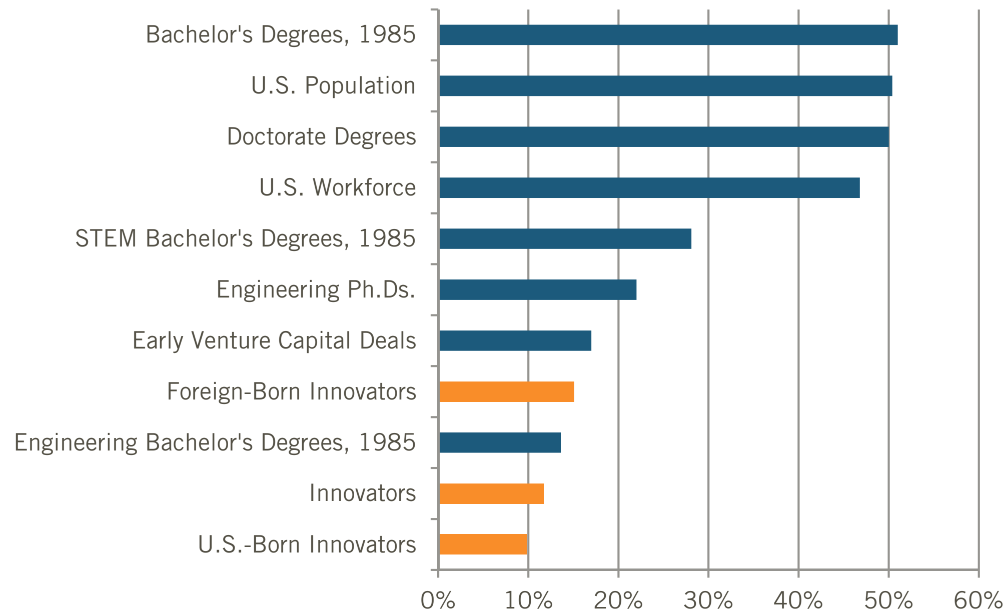
Low female doctoral completion rates in STEM fields can trace its roots to gender imbalances among undergraduates. In 2013, 57 percent of graduates from 4-year bachelor degree programs were women, yet women made up just 36 percent of STEM majors. However, the median respondent on our survey was 47 years of age, meaning that the average innovator was earning her bachelor's degree in the late 1980s when female representation among STEM majors was only 28 percent. Even considering these historically lower rates of female STEM education, women are underrepresented. Given slow growth rates of female inclusion in STEM fields, wide gaps between the numbers of male and female innovators seem likely to persist for the foreseeable future.

Figure 3: Percentage of Women Receiving Bachelor's Degrees, by Major, 1970 to 2013[61]



Female innovators are also significantly younger than males, showing that gender gaps widen as the age of innovators increase. This could be because the STEM education gender gap is shrinking over time. However, we cannot assume the education gender gap is decreasing over time, as women might simply tend to innovate at earlier ages.

Figure 4: Percentage of Female Representation in Various Populations, as Percentage of U.S. Totals (Blue) and Percentage of Responding Innovators (Orange)[62]



In summary, women have very low representation among survey respondents. Even taking into account lower rates of education in advanced STEM degrees, currently and historically, women, especially those born in the United States, account for a much lower percentage of innovators.

Ethnicity and Country of Origin

Examining the ethnic breakdown of innovators in the United States, it is apparent that immigrants play a very large role in innovation. On the other hand, minorities born in the United States are represented at very low rates.

Table 7: U.S.-Born Share of U.S. Population and of Survey Respondents, by Ethnicity

Ethnicity of U.S.-Born Innovators	Percent of Innovation Sample	Percent of United States Population	Rate of Representation
White	59.6%	59.2%	1
Asian	1.5%	1.8%	0.8
Black or African American	0.3%	11.3%	0.0
Hispanic	1.4%	11.5%	0.1
Two or More Races	0.9%	1.9%	0.5
Native American	0.9%	0.9%	1.1
Total U.S.-Born	64.5%	86.5%	0.7

Table 8: Foreign-Born Share of U.S. Population and of Survey Respondents, by Region of Origin

Region of Origin for Foreign-Born Innovators	Innovation Sample	United States Population	Rate of Representation
Europe	12.6%	1.5%	8.2
Asia	17.8%	3.9%	4.5
Mexico	0.4%	3.9%	0.1
Other Latin America	1.2%	3.2%	0.4
Other	3.5%	0.9%	3.8
Total Foreign-Born	35.5%	13.5%	3.8

Blacks and Hispanics born in the United States account for 22.8 percent of the population, yet just 1.7 percent of responding innovators.

In Tables 7 and 8, the U.S. population and responding innovators are broken into percentages based on the ethnicity of individuals born in the United States and the country of origin of those born abroad. Presented side-by-side, it is clear that some groups are under- or overrepresented among respondents. Immigrants from Europe and Asia, for instance, make up over 30 percent of responding innovators but less than 4.5 percent of U.S. residents. By contrast, Blacks and Hispanics born in the United States account for 22.8 percent of the population, yet just 1.7 percent of responding innovators. The following section discusses in depth the relative impact and prevalence of innovators depending on race, ethnicity, country of origin, and immigration status.

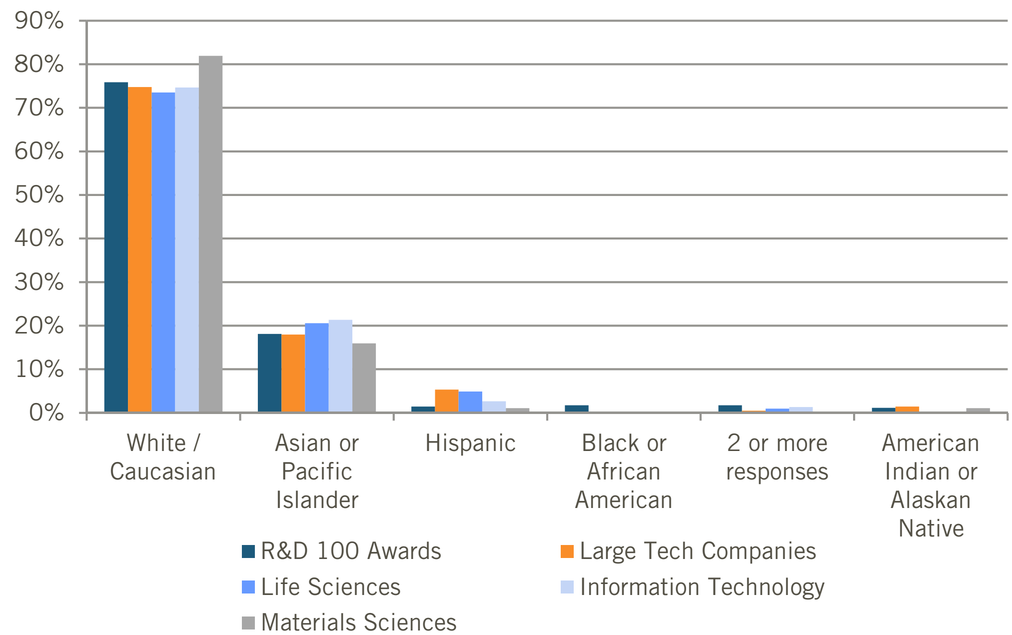
Ethnicity

Looking at the entire sample, White innovators accounted for 75.6 percent of the sample. Individuals of Asian or Pacific Islander ethnicity made up the second largest group at 18.7 percent. Of the remainder, 3.3 percent were Hispanic; 0.4 percent were Black or African American; and American Indians and Alaskan Natives, and those listing two or more responses represented 1 percent each.

Table 9: Innovators by Sample and Ethnicity[63]

Sample	White/ Caucasian	Asian or Pacific Islander	Hispanic	Black or African American	2 or more responses	American Indian or Alaskan Native
R&D 100 Awards	75.9%	18.1%	1.4%	1.7%	1.7%	1.1%
Large Tech Companies	74.8%	18.0%	5.3%	0.0%	0.5%	1.5%
Life Sciences	73.5%	20.6%	4.9%	0.0%	1.0%	0.0%
Information Technology	74.7%	21.3%	2.7%	0.0%	1.3%	0.0%
Materials Sciences	81.9%	16.0%	1.1%	0.0%	0.0%	1.1%
Total	75.6%	18.7%	3.3%	0.4%	1.0%	1.0%

Figure 5: Ethnicity of Innovators, by Sample



Ethnic distributions were consistent across samples. However, triadic patents filers in life sciences and information technology are slightly more diverse than other samples. With 81.9 percent, materials sciences patents have the largest share of White innovators.

Much of the ethnic diversity among respondents, however, comes from the substantial pool of immigrants. For example, 91.4 percent of Asian innovators were born outside the United States. Similarly, more than half of the Hispanic population represents immigrants from South and Central America. Four out of six respondents identifying as Black (out of the total respondent pool of 923) were immigrants from Africa.

Table 10: Ethnicity of U.S.-born Innovators, by Sample

Sample	White / Caucasian	Asian or Pacific Islander	Hispanic	Black or African American	2 or more responses	American Indian or Alaskan Native
R&D 100 Awards	92.3%	3.0%	0.4%	0.9%	1.7%	1.7%
Large Tech Companies	90.1%	2.3%	4.6%	0.0%	0.8%	2.3%
Life Sciences	93.4%	0.0%	4.9%	0.0%	1.6%	0.0%
Information Technology	93.5%	2.2%	2.2%	0.0%	2.2%	0.0%
Materials Sciences	96.9%	1.5%	0.0%	0.0%	0.0%	1.5%
Total	92.4%	2.3%	2.1%	0.4%	1.4%	1.4%

Considering only the sample born in the United States, 92.3 percent were White, 3 percent were Asian, and 2.1 percent were Hispanic. Despite representing 13.2 percent of the U.S. population, only two U.S.-born innovators reported as Black, representing less than half a percent of the U.S.-born group of innovators.[64] Multiracial or "Other" respondents had 1.4 percent, with eight responses, as did Native American respondents.

Asian Americans represent only 2.3 percent of U.S.-born innovators. Considering the substantial contributions to innovation that Asians born outside of the United States have, as well as the high average education levels for this demographic, this result is very surprising.[65] In fact, U.S.-born Asian innovators are underrepresented in the sample.

As with gender imbalances, lower levels of minority involvement in innovation is related to educational attainment. Not only do Blacks and Hispanics have low rates of involvement in these innovations, they are underrepresented among Ph.D. degree recipients. The percentage of degrees earned by Whites has decreased in the last 35 years, from 92 percent in 1976 to 73 percent in 2011, while the percentage of degrees earned by Asians increased from 2 percent in 1976 to 12 percent of degrees in 2011.

Figure 6: Percentage of Doctoral Degrees, by Race, 1976 to 2011[66]

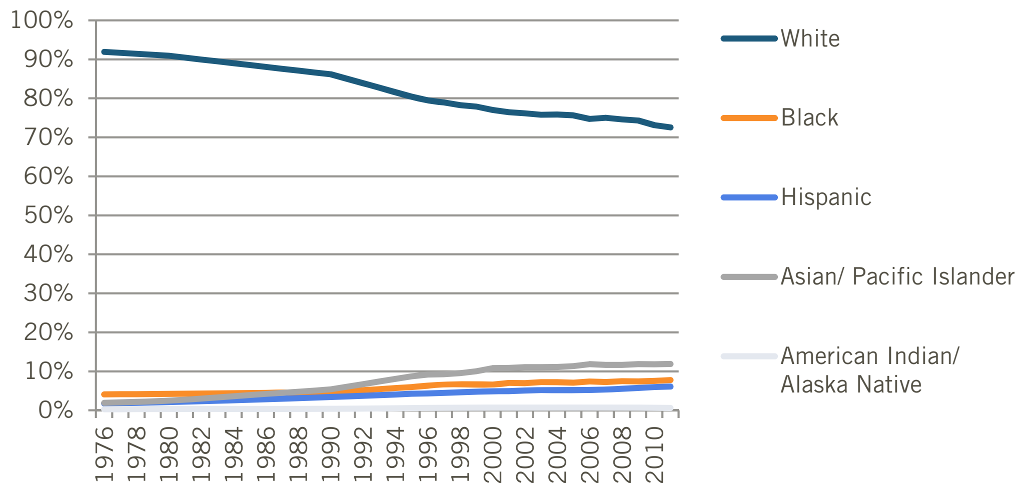
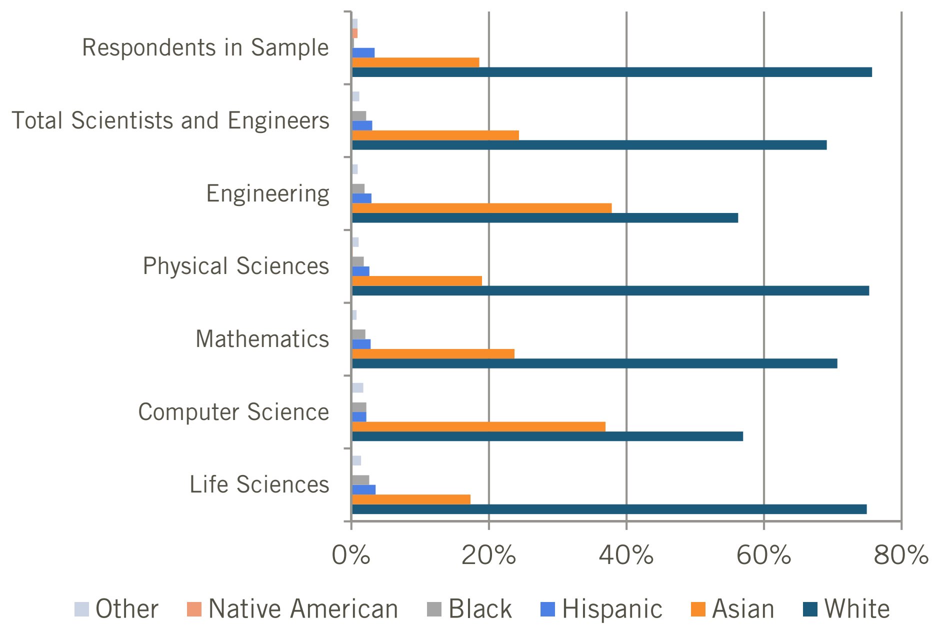


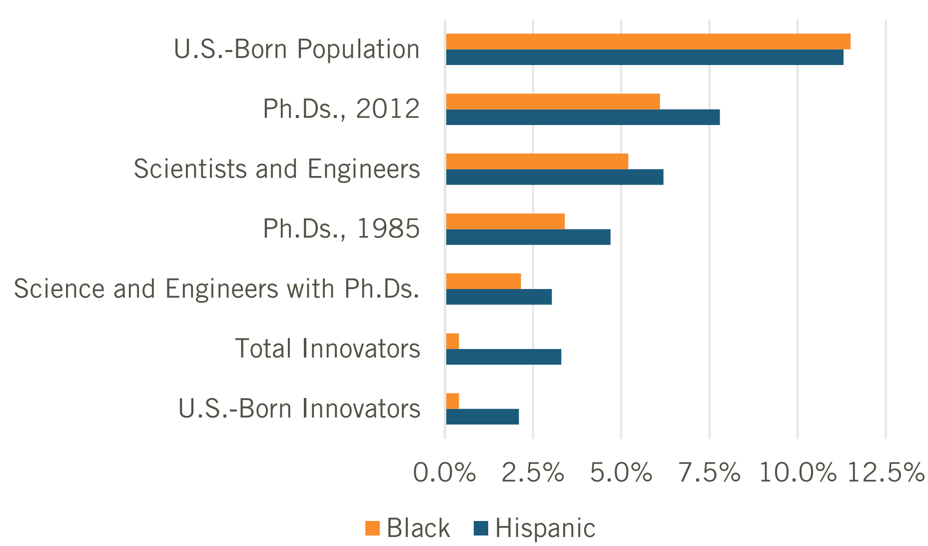
Figure 7: Employed Scientists and Engineers with STEM Doctorates in the United States, by Field of Doctorate, 2013[67]



One reason for the low rates of Blacks and Hispanics among U.S. innovators is their low rate of STEM doctorates.

One reason for the low rates of Blacks and Hispanics among U.S. innovators is their low rate of STEM doctorates. Among total doctoral recipients, Hispanics represent 3 percent of working Ph.D. recipients in STEM fields, which is roughly equivalent to the percentage of Hispanic respondents at 3.4 percent. However, Hispanics represent 17.4 percent of the U.S. population and earn 6.1 percent of total Ph.Ds.[68] Blacks represent just 2.2 percent of working scientists and engineers with STEM doctorates and only 0.4 percent of the responding sample, but represent 13.2 percent of the population and 8 percent of total doctorates.[69]

Figure 8: Percentage of Blacks and Hispanics in the U.S. Population and Among Innovators[70]

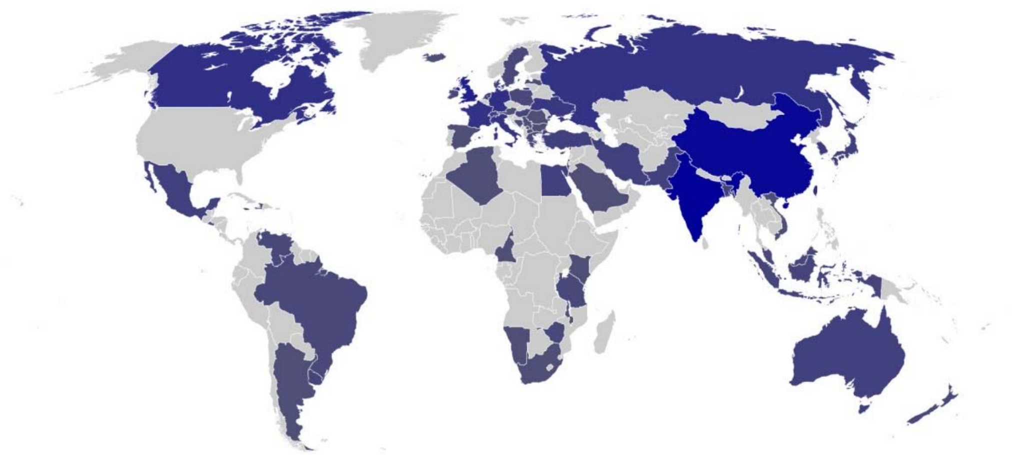


Country of Origin and Immigration Status

First-generation immigrants make up 13 percent of the U.S. population and 16.5 percent of the U.S. workforce, but 35.5 percent of innovators.[71] Highly educated immigrants play a significant role in bolstering the U.S. innovation ecosystem. These findings help demonstrate that the U.S. economy, which faces a serious skills gap in STEM fields, has an outsized demand for foreign talent.[72]

Figure 9: Birthplace Heat Map of Foreign-Born Innovators

First-generation immigrants make up 13 percent of the U.S. population and 16.5 percent of the U.S. workforce, but 35.5 percent of innovators.



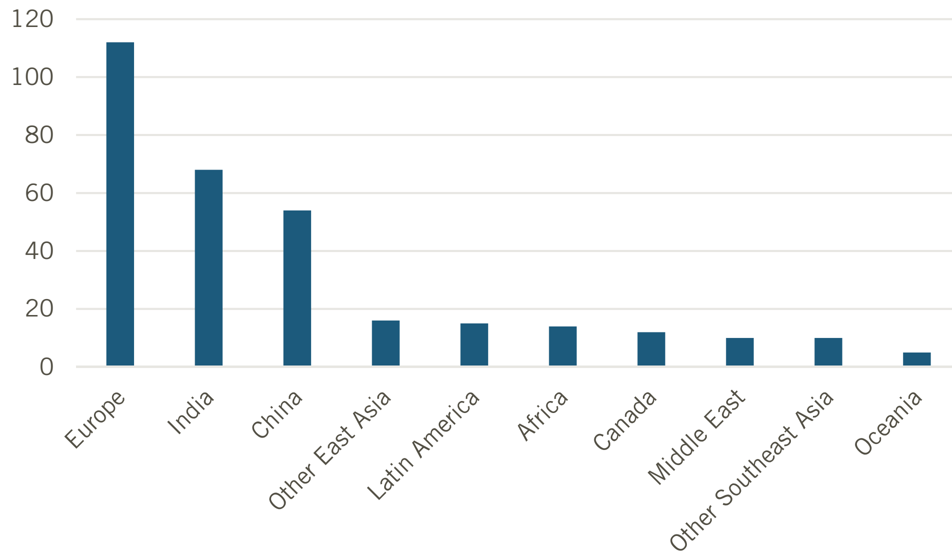
Our sample included respondents born in 62 countries. Of foreign-born innovators, 50.8 percent are naturalized U.S. citizens. 35.5 percent held green cards at the time of innovation, and 8.9 percent held H-1B visas (temporary guest worker visas). Innovators born in India hold 12 of the sample's total 28 H-1B visas, more than any other foreign-born group in our sample.

Table 11: Immigration Status of Innovators

Immigration Status	Respondents	Percent of Foreign-Born Innovators
Born in the United States	568	-
Naturalized U.S. Citizen	159	50.8 %
Green Card Holder	111	35.5%
On H-1B Visa	28	8.9%
Student Visa	6	1.9%
Other Visa	9	2.9%

Innovators hail from all over the world, but the majority were born in Europe, India, or China. Europe accounts for 35.4 percent of foreign-born innovators, Southeast Asia (including India) accounts for 26.6 percent, and East Asia (including China) accounts for 20.3 percent. Africa contributes 4.4 percent of immigrant innovators, most of whom immigrated either from Egypt or Southeast Africa.

Figure 10: Number of Foreign-Born Respondents by Region of Origin[73]



Among individual countries, India and China each contribute a large number of American innovators. However, as discussed in Appendix E, we estimate that Chinese innovators are significantly underrepresented among responding innovators, and that they may make up a larger percentage of the sample than is reported.

The United Kingdom, with 24 innovators, is home to a large percentage of the sample given its size. The United Kingdom's strong system of research universities as well as the common language contributes to its high share of innovating immigrants. Canada, Germany, France, Taiwan, and Russia also contribute a high number of innovators.

Table 12: Countries with Five or more Responding Innovators

Country of Birth	Respondents	Percentage
United States	575	63.7%
India	68	7.5%
China	54	6.0%
United Kingdom	24	2.7%
Canada	12	1.3%
Germany	12	1.3%
France	11	1.2%
Russia	11	1.2%
Taiwan	11	1.2%
Italy	9	1.0%
Ukraine	6	0.7%
South Korea	6	0.7%
Switzerland	5	0.6%

These raw totals, however, do not reflect relative populations of either the country of origin or the size of the immigrant population from that country. Denmark and Switzerland, for example, have only nine total innovators, yet relative to their country populations and the number of immigrants they send to the United States, they outperform the rest of the world. In comparison, immigrants from South America, Central America, and the Caribbean represent 4.8 percent of foreign-born innovators but represent 52.6 percent of the United States' total foreign-born population.[74]

Immigration heritage is also a factor in what types of people innovate. In order to effectively break down the five samples by immigration status, we sorted innovators into five categories: noncitizen adult, naturalized adult immigrant, naturalized child or student immigrant, second-generation American, and third-generation plus, described below in Table 13.

Table 13: Immigration Status Classification

Classification	Description
Noncitizen	Born in another country, on H-1B, green card, student visa, or other visa
Naturalized Adult Immigrant	Born in another country, completed 4-year Degree Abroad, Naturalized U.S. Citizen
Naturalized Child or Student Immigrant	Born abroad to foreign parents, completed 4-year degree in United States, Naturalized U.S. citizen
2nd-Generation American	One or both parents born abroad
3rd-Generation Plus	Born in United States to U.S.-born parents, or born abroad to U.S.-born parents but U.S. citizen from birth

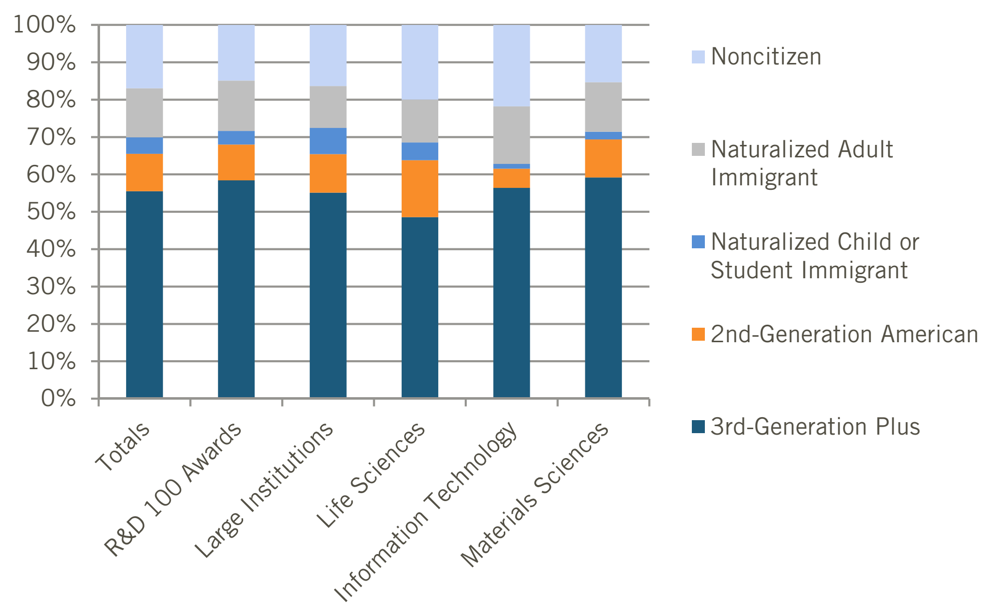
At 55.5 percent, third-generation plus Americans still make up the majority. The percentage of third-generation or greater Americans by sample ranges from 59.2 percent among materials sciences patent filers to 48.6 percent, less than half, of life sciences patent filers. Second-generation Americans make up a total of 10 percent of innovators.

Examining immigrant representation by sample, innovators in life sciences and information technology were the most likely to be noncitizens, at over 20 percent in each category. Materials science patents had the lowest share of immigrants, at 30.6 percent, while 38.5 percent of information technology patent filers were born abroad. Life sciences patent filers were more likely to be second-generation Americans, while information technology patent filers were less likely to be second-generation Americans. Patent filers employed at large tech companies, meanwhile, were more likely to have immigrated as children or students and attended a U.S. college or university for their undergraduate education.

Table 14: Immigration Status Percentages, by Sample

Country of Birth	3rd-Generation Plus	2nd-Generation American	Naturalized Child or Student Immigrant	Naturalized Adult Immigrant	Noncitizen
Totals	55.5%	10.0%	4.4%	13.1%	17.0%
R&D 100 Awards	58.4%	9.6%	3.7%	13.5%	14.9%
Large Tech Companies	55.1%	10.3%	7.0%	11.2%	16.4%
Life Sciences	48.6%	15.2%	4.8%	11.4%	20.0%
Information Technology	56.4%	5.1%	1.3%	15.4%	21.8%
Materials Sciences	59.2%	10.2%	2.0%	13.3%	15.3%

Figure 11: Immigration Classification, by Sample



It is also useful to compare innovators who are responsible for the innovations this study examined with the population of U.S. scientists and engineers as a whole. Presumably, virtually all innovators are scientists or engineers, though only a subset produces innovations on par with triadic patents in key fields or to R&D 100 Awards standards. We would expect for all scientists and engineers to have a relatively equal chance at producing a high-level innovation, but as Table 15 below shows, this does not appear to be the case.

Data from the National Science Foundation divides scientists and engineers working in the United States by citizenship status. United States citizens include immigrants who have since naturalized. The percentage of noncitizen scientists and engineers matched the percentage of innovators in the sample at roughly 18 percent, yet breakdowns within this category varied.

Among U.S. citizens, White U.S.-born or naturalized scientists and engineers are more likely to reach the top tier of innovation. Hispanic and Black scientists and engineers born in the United States are disproportionately less likely to have produced leading innovations, constituting 11.4 percent of scientists and engineers but only 2.9 percent of responding innovators.

Among U.S. citizens, White U.S.-born or naturalized scientists and engineers are more likely to reach the top tier of innovation.

Table 15: Ethnicity of U.S.-Born Scientists and Engineers, Compared with U.S.-Born Innovators in Sample[75]

Ethnicity	U.S. Scientists and Engineers	Innovators	Rate of Representation
White	59.5%	66.9%	1.1
Asian	9.5%	10.8%	1.1
Hispanic/Latino	6.2%	2.2%	0.4
Black	5.2%	0.7%	0.1
Other	1.5%	1.0%	0.7
American Indian/Alaskan Native	0.2%	0.9%	4.5
Total U.S. Citizens	82.1%	82.5%	1.0

Table 16: Country of Origin of Noncitizen U.S. Scientists and Engineers, Compared with Noncitizen Innovators in Sample[76]

Country or Region of Origin	U.S. Noncitizen Scientists and Engineers	Noncitizen Innovators	Rate of Representation
China	1.5%	1.3%	0.9
India	3.3%	4.1%	1.2
Other Asia	5.4%	2.9%	0.5
Europe	2.9%	6.6%	2.3
Africa	1.1%	0.9%	0.8
Latin America	2.8%	0.5%	0.2
Canada	0.7%	0.9%	1.3
Oceania	0.1%	0.3%	3.0
Total, Non-Citizens	17.8%	17.5%	1.0

The percentage of non-naturalized immigrants producing innovations in our sample matches the percentage of non-naturalized immigrant scientists and engineers. However, non-naturalized European and Oceanic scientists and engineers are more likely to have produced innovations, representing 6.9 percent of responses, but making up just 3 percent of U.S. scientists and engineers. The shares of Chinese, Indian, Canadian, and African scientists and engineers were roughly comparable to the share of innovators, while non-naturalized scientists and engineers from Latin America and "other Asia" were less likely to produce innovations.

Education

By understanding the educational background of the United States' top innovators, policymakers and administrators can make more informed decisions about STEM education. Do innovators concentrate on specific fields or subject areas? Do they attain certain advanced graduate degrees with high frequency? Do they attend elite private colleges, or are they trained at a variety of institutions? We asked innovators a series of questions to understand the tertiary educational paths that eventually lead to innovations.

Undergraduate Degrees

The undergraduate experience forms the foundational building block for innovators. Only 3 percent of the sample lack a four-year undergraduate degree. Of the sample, 30.4 percent attained their undergraduate degrees in another country.[77] More innovators attended public U.S. colleges and universities than private, at 39.5 percent and 27.1 percent respectively. Of students completing an undergraduate degree in the United States, roughly two-fifths attended private schools.

More innovators attended public U.S. colleges and universities than private, at 39.5 percent and 27.1 percent respectively.

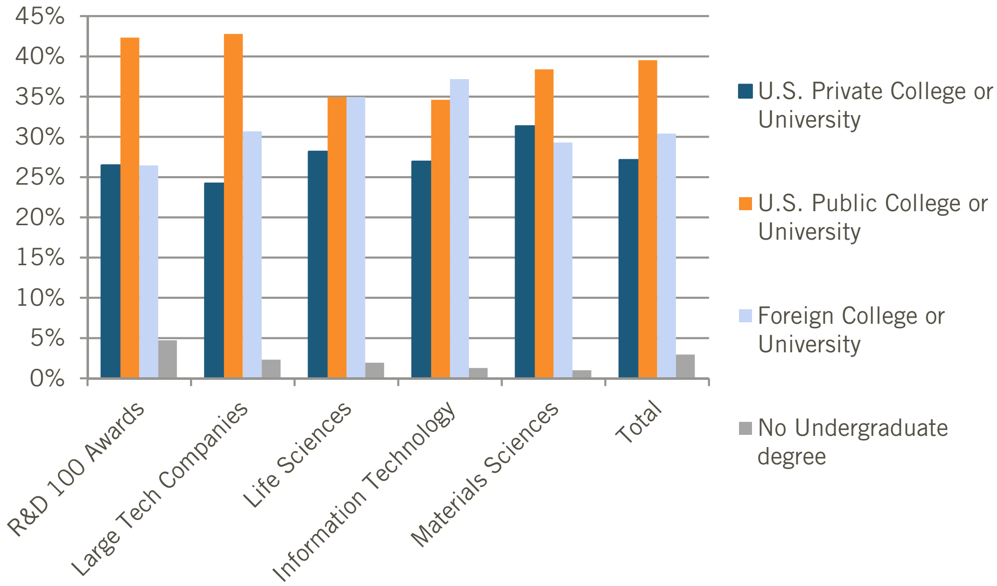
Table 17: Type of Undergraduate Institution, by Sample

Sample	U.S. Private College or University	U.S. Public College or University	Foreign College or University	No Undergraduate Degree
R&D 100 Awards	26.5%	42.3%	26.5%	4.7%
Life Sciences	28.2%	35.0%	35.0%	1.9%
Information Technology	26.9%	34.6%	37.2%	1.3%
Materials Sciences	31.6%	33.5%	32.3%	1.0%
Large Tech Companies	24.2%	42.8%	30.7%	2.3%
Total	27.1%	39.5%	30.4%	3.0%

Discounting those without a university degree or those who graduated from a foreign university, public university graduates still outweigh private university graduates. Public institutions enroll 76 percent of all undergraduate students in the United States, compared with the 59.3 percent of degrees awarded by public institutions observed in the sample.[78]

Public institutions also grant a comparatively larger percentage of STEM degrees. In 2011, 69 percent of bachelor's degrees in STEM fields came from public institutions, compared with 26 percent from not-for-profit private universities.[79] Therefore, if all institutions produced innovators at the same rate among STEM graduates, we would expect public institutions to educate over 70 percent of innovators. However, it seems that graduates from private colleges and universities are more likely to become innovators. They are overrepresented among the innovation sample by a ratio of 1.5, as expected, given that many of the top research universities in the United States are private.

Figure 12: Undergraduate Institution, by Sample



Innovators seldom hold degrees in social sciences, business, and the humanities, implying that to achieve higher levels of innovation, the United States should encourage more students to pursue four-year STEM degrees.

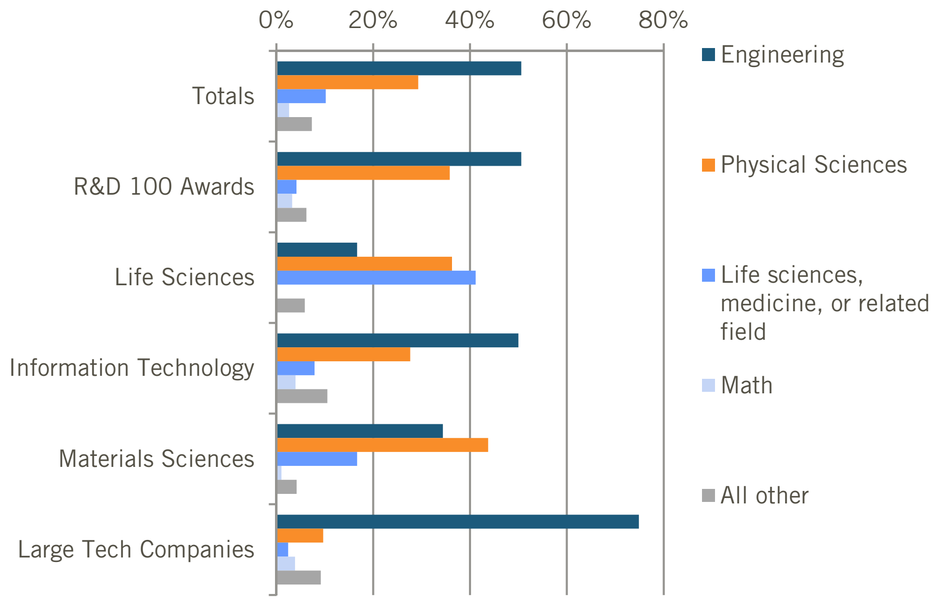
Breaking this result down by sample, innovators at large tech companies typically graduated from public U.S. colleges or universities. Meanwhile, innovators in specific samples, especially those filing materials sciences patents, were more likely to attend a private U.S. college or university.

STEM fields, including engineering, physical and life sciences, and math, make up 93.1 percent of total undergraduate degrees in the sample. Over half of respondents with four-year degrees studied engineering, reinforcing the importance of this discipline to U.S. innovation. Physical and life sciences are also popular majors among innovators, at 28.4 percent and 9.9 percent of undergraduate degrees respectively. By comparison, few innovators studied social science, business, or the humanities. To achieve higher levels of innovation, the United States should encourage more students to pursue four-year STEM degrees.

Table 18: Major Subject Area of Four-year Degree

Undergraduate Major	Respondents	Percentage
Engineering	442	49.1%
Physical sciences	256	28.4%
Life sciences, medicine, or related field	89	9.9%
Other	27	3.0%
Math	23	2.6%
Social sciences	18	2.0%
Business	13	1.4%
Humanities	6	0.7%
No Undergraduate Degree	27	3.0%

Figure 13: Undergraduate Major, by Sample[80]



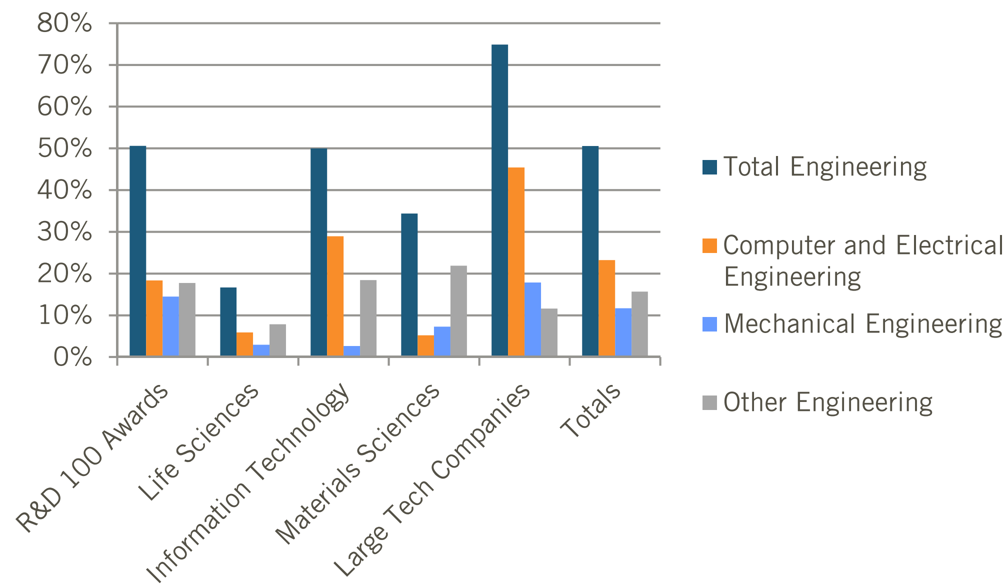
74.2 percent of large tech company patent filers studied engineering as undergraduates. While engineering was the most common major in the entire sample, in some individual samples other majors were dominant. Life sciences innovators predictably held a high share of life sciences, medicine, and related fields majors, at 42.9 percent, though physical sciences majors, at 37.8 percent, are also very common here. In materials sciences, physical science was the most common major, at 45.2 percent of respondents.

Table 19: Engineering Major Concentrations, by Sample, and Breakdown of Types of Engineering, by Sample

Engineering Major Composition by Sample	Engineering Percent of Total Four-year Degrees	Percent Computer and Electrical	Percent Mechanical	Percent Other Engineering Field
R&D 100 Awards	50.6%	36.3%	28.7%	35.1%
Life Sciences	16.7%	35.3%	17.6%	47.1%
Information Technology	50.0%	57.9%	5.3%	36.8%
Materials Sciences	34.4%	15.2%	21.2%	63.6%
Large Tech Companies	74.9%	60.6%	23.9%	15.5%
Totals	50.6%	45.9%	23.1%	31.0%

Of engineering degrees, 45.9 percent specialized in computer or electrical engineering, 23.1 percent in mechanical engineering, with the remaining 31 percent in other engineering fields. Much of the concentration of engineer majors in the large tech companies sample consists of computer and electrical engineers. Meanwhile, R&D 100 Award winners saw the highest concentration of mechanical engineering degrees.

Figure 14: Type of Engineering Major, by Sample



Advanced Degrees

Of respondents, 77.6 percent of innovators have advanced degrees beyond a four-year bachelor's degree, and many hold more than one. The 923 responding innovators hold a total of 1,075 advanced degrees, including 514 Ph.Ds., 465 master's degrees, 46 M.B.A.s, and 14 medical degrees.

Table 20: Advanced Degrees per Innovator

Advanced Degree	Innovators with Degree
Ph.D.	514
Master's	465
M.B.A.	46
Other	33
M.D.	14
J.D.	2
Total Advanced Degrees	1,075

Similar to undergraduate degree attainment, the majority of innovators holding graduate degrees received those degrees from public institutions rather than private ones. Over half of total advanced degrees and 64 percent of degrees earned in the United States were from U.S. public universities.

Table 21: Advanced Degrees Granted, by Type of University

University Type	Percentage of Advanced Degrees Granted
U.S. Public University	50.1%
U.S. Private University	28.2%
Foreign University	20.5%
For-Profit University	0.7%

The prevalence of advanced degrees awarded by U.S. public universities was unexpected. Unlike undergraduate degrees, where public universities award twice the number of degrees as public universities, public and not-for-profit private universities award nearly the same number of advanced degrees. Public institutions account for 46.1 percent of master's degrees and 49.4 percent of Ph.Ds., but train 63.1 percent of responding innovators who earned a degree in the United States. Private institutions account for 43.5 percent of master's degrees and 46.6 percent of Ph.Ds., yet only train 35.4 percent of innovators earning advanced degrees in the United States.[81]

Public institutions account for 46.1 percent of master's degrees and 49.4 percent of Ph.Ds., but train 64 percent of responding innovators.

Table 22: Universities Issuing at Least Five Degrees to Innovators in Sample

University	Responses	Type
Massachusetts Institute of Technology	16	Private
University of Illinois at Urbana-Champaign	14	Public
University of California Berkeley	11	Public
University of Texas at Austin	10	Public
University of Michigan	9	Public
University of Arizona	8	Public
Cornell University	8	Private
Rensselaer Polytechnic Institute	7	Private
Stanford University	7	Private
California Institute of Technology	6	Private
Georgia Institute of Technology	6	Public
Harvard University	6	Private
Ohio State University	6	Public
University of Virginia	6	Public
Carnegie-Mellon University	5	Private
Case Western Reserve University	5	Private
Chinese Academy of Science	5	Foreign
North Carolina State University	5	Public
State University of New York at Buffalo	5	Public
University of California Los Angeles	5	Public
University of Connecticut	5	Public
University of Washington	5	Public

For-profit private universities (educational institutions operated by private, profit-seeking businesses) award 10.4 percent of master's degrees and 9.2 percent of Ph.Ds. in the United States. These schools often provide more technical, or vocational-focused degrees, and less than one percent of advanced degrees received by innovators come from for-profit universities.[82]

The United States' top-ranked private universities were centers of innovations, but so were many of its public research universities. The Massachusetts Institute of Technology, the California Institute of Technology, Rensselaer Polytechnic Institute, Stanford University, and Harvard were among the universities awarding the most advanced tertiary degrees to respondents. However, only 8 of 22 universities with five or more degrees granted to respondents were private. Of the top 22 universities on this metric, 13 were large, public universities, led by the University of Illinois and including the University of California Berkeley, the University of Texas at Austin, and the University of Michigan. All told, the University of California public university system awarded 26 degrees, or 6.2 percent of universities listed by respondents. Only one foreign university, the Chinese Academy of Science, awarded five or more degrees to responding innovators.

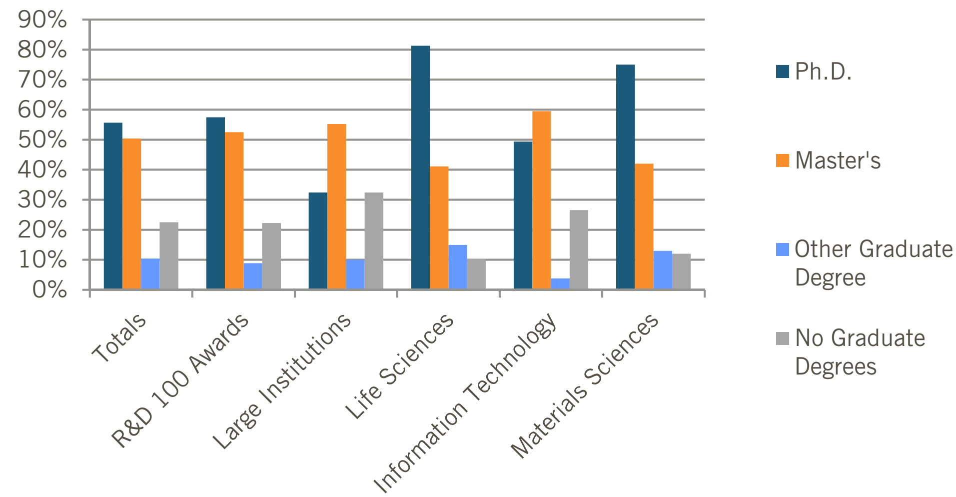
With 1.5 advanced degrees per innovator, immigrant innovators have on average 0.4 more advanced degrees then do U.S.-born innovators.

At 55.7 percent, the majority of innovators hold Ph.Ds. Among materials sciences and life sciences patent filers, a Ph.D. seems almost required, with 75 percent and 81.3 percent of innovators holding doctorates respectively. In all samples, even among large tech company patent filers where Ph.Ds. are rarer, the vast majority of innovators hold some form of advanced degree. Much of the variance between samples relates to knowledge requirements in different fields. Life sciences research appears to require a doctoral degree to reach the forefront of knowledge in a specific area or concentration, while information technology and computing are still-developing fields, and the requisite expertise can in some cases be reached with just a master's degree.

Table 23: Innovators with Advanced Degrees by Degree Type, by Sample

Advanced Degrees by Sample	Ph.D.	Master's	Other Graduate Degree	No Graduate Degrees
Totals	55.7%	50.4%	10.4%	22.5%
R&D 100 Awards	57.5%	52.5%	8.9%	22.2%
Large Tech Companies	32.4%	55.3%	10.0%	32.4%
Life Sciences	81.3%	41.1%	15.0%	10.3%
Information Technology	49.4%	59.5%	3.8%	26.6%
Materials Sciences	75.0%	42.0%	13.0%	12.0%

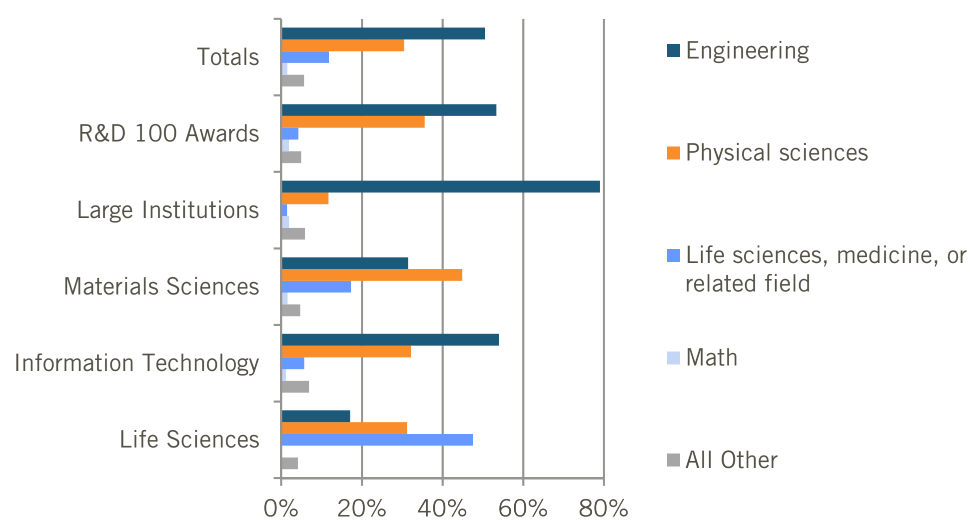
Figure 15: Percentage of Innovators with Advanced Degrees, by Sample



While half of U.S.-born innovators hold Ph.Ds., 67.9 percent of foreign-born innovators have earned doctorates.

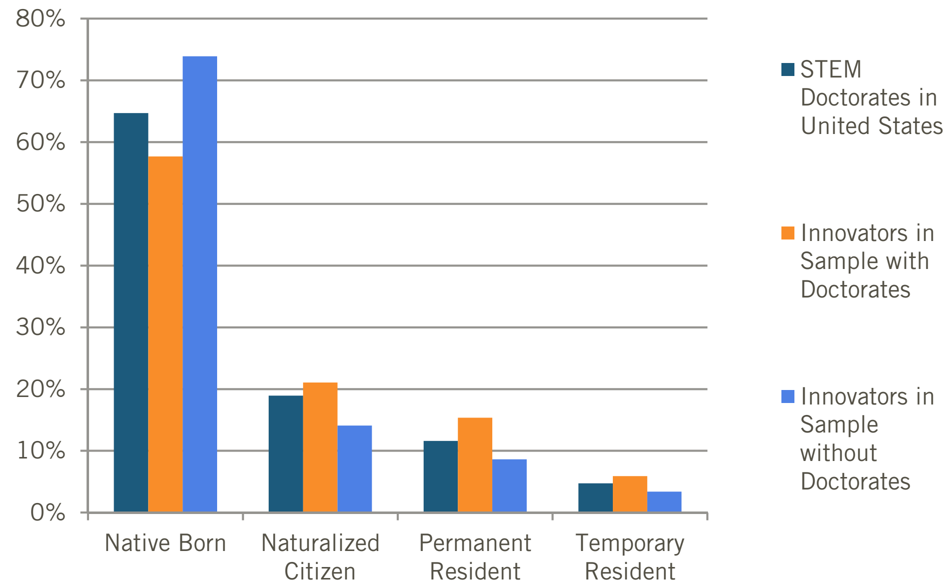
As with undergraduate majors, the most common field for advanced degrees was engineering, accounting for 50.5 percent of advanced degrees. The physical sciences field accounts for 30.5 percent of degrees, while math degrees constitute 1.5 percent of degrees. Life sciences degrees represent 11.8 percent, but these are mostly concentrated among life sciences patent holders, where 47.6 percent of advanced degrees are in life sciences fields.

Figure 16: Extent of Graduate Education Degrees by Field, by Sample



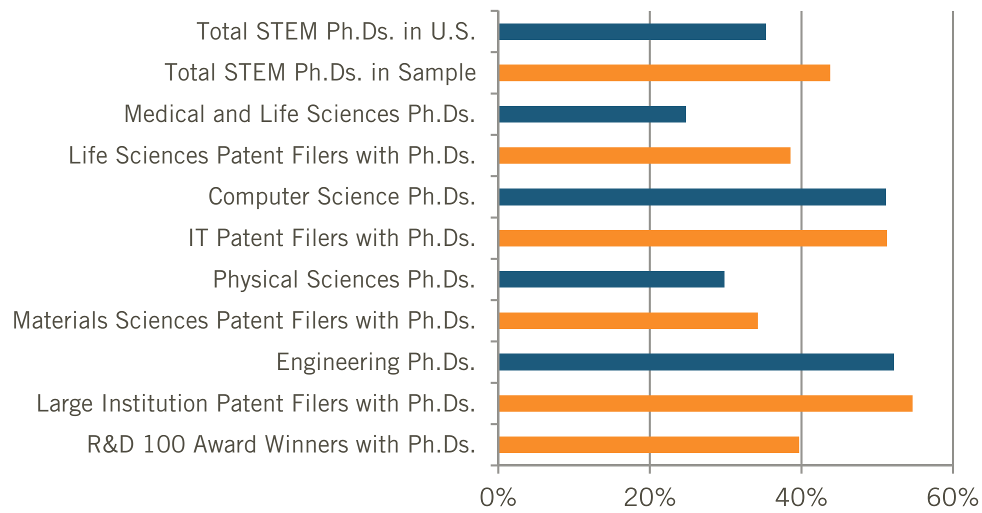
On average, innovators born abroad hold more degrees than do their native-born counterparts despite being younger, and a much higher percentage of foreign-born innovators hold Ph.Ds. With 1.5 advanced degrees per innovator, immigrant innovators have on average 0.4 more advanced degrees then do U.S.-born innovators. While half of U.S.-born innovators hold Ph.Ds., 67.9 percent of foreign-born innovators have earned doctorates.[83] In fact, of responding innovators with doctorates, 43.8 percent are immigrants.

Figure 17: Immigration Status of STEM Doctorates, 2013[84]



Even among U.S. scientists and engineers with Ph.Ds., immigrants are overrepresented in the sample, reinforcing the idea that STEM immigration attracts the global "best and brightest." Workers with STEM doctorates in the United States are more likely to innovate if they were born abroad. In fact, there is a 16.2 percentage point gap between the percentage of native-born innovators with and without Ph.Ds. Additionally, there is a smaller yet significant gap of 7 percentage points between the native-born doctorate degree holders employed as scientists and engineers in the United States and native-born responding innovators with Ph.Ds.

Figure 18: Share of Immigrants Among Ph.D. Holders in the United States (Orange) and in the Sample (Blue), by Sample and Doctorate Field[85]



Even among U.S. scientists and engineers with Ph.Ds., immigrants are overrepresented in the sample. This suggests that STEM immigration attracts the global "best and brightest."

Age

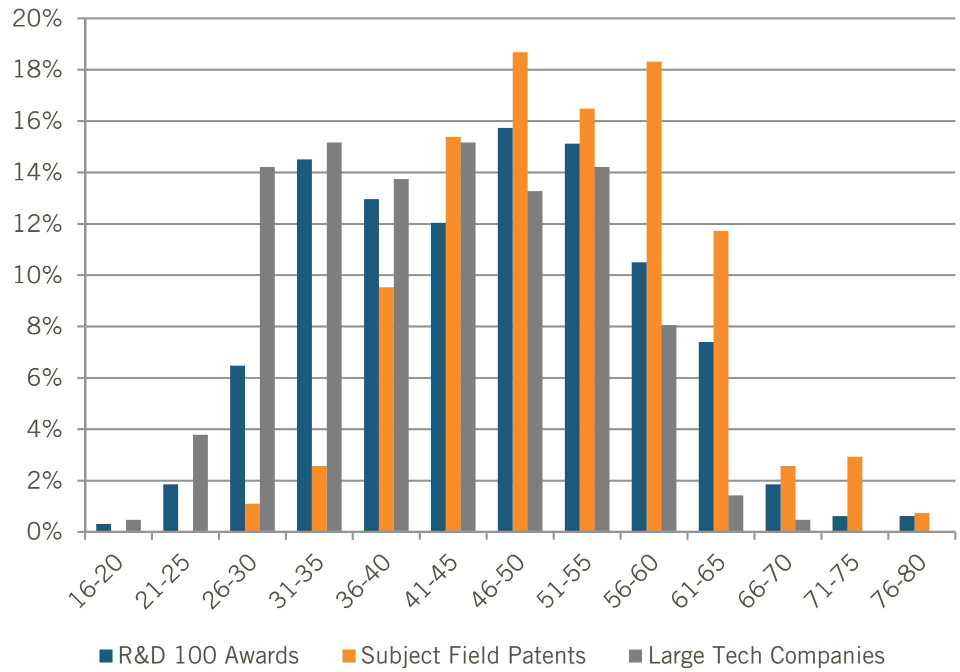
Innovators in our sample ranged in age from 18 to 80 at the time of innovation, with an overall median of 47 years and a standard deviation of 10.9 years.[86]

Table 24: Age of Innovators, by Sample

Sample	Median Age
R&D 100 Awards	46
Large Tech Companies	44
Life Sciences	50
Information Technology	51
Materials Sciences	53
Total	47

In our study, innovation peaks among innovators between 46 and 50 years of age. However, rates of innovation are also very high between the ages of 41 and 55. Innovation seems to decline sharply after 65, the median expected retirement age of the American workforce.[87] Indeed, only 30 innovators, or 3.5 percent of the sample, were aged 66 or older. Similarly, only 49 innovators, or 5.8 percent of the sample, are 30 or younger. Innovation is also common among individuals in their thirties, though a large number of these innovators belong to the large tech companies' sample.

Figure 19: Age Distribution at Time of Innovation by Five-Year Intervals, by Sample

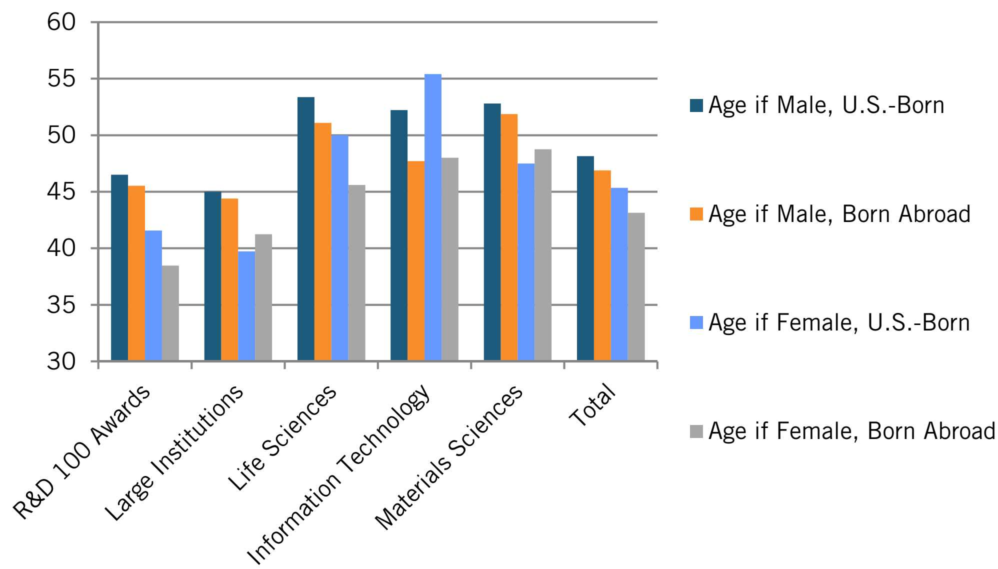


Instead of an even distribution across the age cohort of typical working adults, age distributions across all samples skewed toward adults in the latter half of their careers, especially among patent filers in life sciences, materials sciences, and information technology. Possibly due to larger team sizes, R&D 100 Award winners had the most variance, with a standard deviation of 11.2 years compared with 10.4 years among large tech company patent filers and 9.7 years among other patents filers.

The median age of innovators at the large companies we sample is seven years younger than that of the median innovators filing for a triadic patent in life sciences, materials sciences, and information technology. Part of this difference may relate to the time required to gain deep expertise in a particular area. Among advanced degree holders, the average age for an innovator with a Ph.D. is 2.4 years older than an innovator without a Ph.D.[88]

The average age for innovators in large tech companies is still older than the overall average age of the United States workforce, 41.9 years.[89] Innovators in other categories, however, are much older than the average worker in the United States.

Figure 20: Average Age of Innovator at Time of Innovation, by Gender and Place of Birth



Male innovators tend to be older than female innovators, and U.S.-born innovators tend to be older than those born abroad. At 48 years at the time of innovation, the median male innovator born in the United States is five years older than the median female innovator born abroad, at 43 years of age. Foreign-born males have a median of 47 years of age, while females born in the United States have a median of 45 years.[90] This is true across almost every sample (though low sample sizes of U.S.-born female innovators among information technology patents filers resulted in a higher median age among that sample).

Figure 21: Age Distribution at Time of Innovation by Five-Year Intervals, by Gender

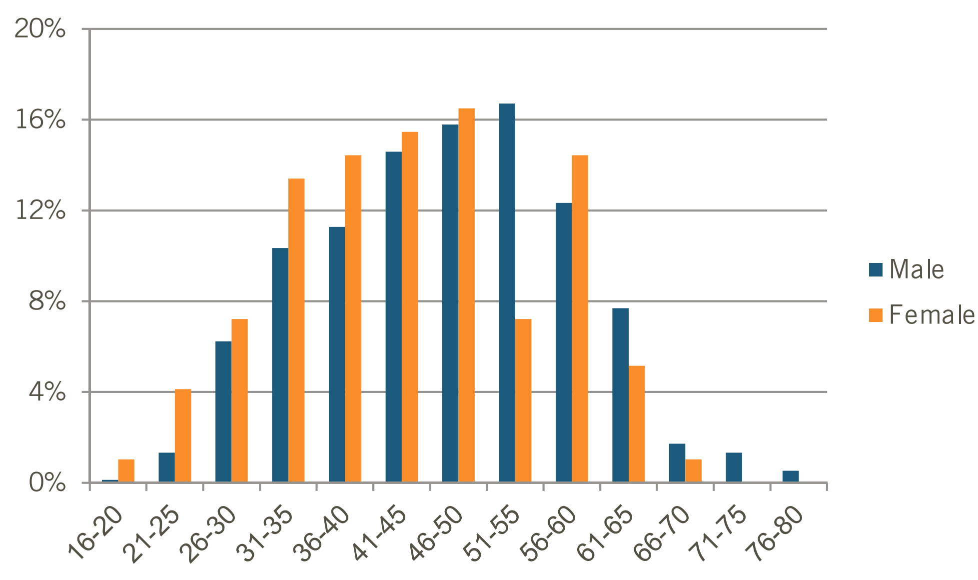
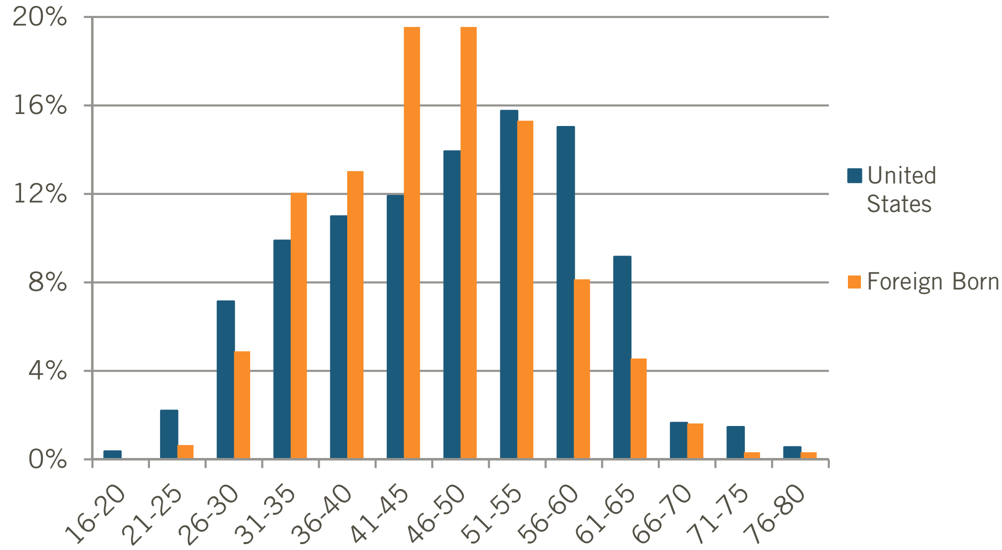


Figure 22: Age Distribution at Time of Innovation by Five-Year Intervals, U.S.-Born and Foreign-Born



In high-tech fields that require deep expertise, the average innovator in life sciences, materials sciences, and information technology is much older than the median age of the American workforce.

U.S.-born innovators, both males and females, had greater standard deviations than did foreign-born innovators, who tended to be in their late thirties, forties, and early fifties.[91] Relationships among the four groups presented in Figure 20 were not strong enough to constitute statistical significance, partly because of a smaller sample size. However, the difference both in age between males and females and innovators born in the United States and born abroad are statistically significant at the 5 percent confidence level.[92]

These results counter the popular narrative that young innovators in Silicon Valley dominate innovation in the United States. Instead, individuals in their late careers with significant experience and education in their fields predominately create innovations. Moreover, we observe in patent samples from high-tech fields that require deep expertise that the average innovator in life sciences, materials sciences, and information technology is much older than the median age of the American workforce.

Innovations

The survey asks questions concerning *innovations* in addition to questions concerning *innovators*. This section analyzes the characteristics and team demographics of innovations rather than the characteristics of individual respondents. The survey methodology allowed multiple innovators contributing to the same innovation to respond. Presenting information on innovation rather than individual responses prevents counting multiple responses regarding the same innovation. For example, it is more useful to know what percentage of innovations were supported by public grants than to know how many innovators worked on projects receiving these grants.

In examining innovations, we seek to ask questions such as:

- How old was the company at the time of innovation?
- Was this company a startup venture?
- Where did the innovation take place?
- Was the innovation the product of collaboration with another institution, and what types of institutions collaborated?
- What types of public grants helped fund the innovation?
- What were the most significant barriers encountered in efforts to commercialize the innovation?
- What has been the approximate cumulative revenue resulting from the innovation?

To learn about characteristics of specific innovations, we map individual innovator responses to their respective innovations. We were able to match 732 respondents to 572 innovations. Multiple responses for the same innovation are combined.[93]

Universities accounted for 7.3 percent of innovations, while governmental organizations and public research labs accounted for 12.5 percent of innovating institutions among R&D 100 Awards and subject field patents.

Table 25: Innovations with Innovators' Responses, by Sample

Sample	Innovations in Sample	Total Responses	Innovations with at least one Response	Percentage of Innovations with at least one Response
R&D 100 Awards	398	274	171	43.0%
Materials	392	100	87	22.2%
Life Sciences	398	111	90	22.6%
Information Technology	397	83	75	18.9%
Large Tech Companies	1,066	164	149	14.0%
Total	2,651	732	572	21.6%

With multiple innovators for most innovations, this methodology offers multiple opportunities for getting a response. As a result, the response rate for innovations is much higher than the response rate for individual innovators, thus reducing the possibility of response bias. While the overall response rate was 9.6 percent, the number of innovations for which we have at least one response was 21.6 percent. For R&D 100 Awards, where teams are large, and it was more likely to get at least one response, 43 percent of innovations had responses. Life sciences, materials sciences, and information technology patents averaged 21.2 percent.

Innovating Institutions

Private companies were behind 80.2 percent of triadic patents in life sciences, materials science, and information technology and R&D 100 Award-winning innovations. Of these, roughly three-fourths are publicly traded companies. Universities accounted for 7.3 percent of innovations, while governmental organizations and public research labs accounted for 12.5 percent of innovating institutions among R&D 100 Awards and subject field patents. For large tech companies, institution information is already known and dependent on the collection method. Therefore, this sample is excluded from the following section.

Table 26: Innovation by Type of Institution, by Sample[94]

Sample	Government Organization/Public Research	University	Publicly Traded Company	Privately Owned Company
R&D 100 Awards	38.7%	11.0%	20.8%	29.5%
Materials Sciences	0.4%	7.9%	63.3%	28.4%
Life Sciences	4.8%	15.5%	54.8%	25.0%
Information Technology	1.4%	3.7%	76.4%	18.5%
Total	12.5%	7.3%	59.5%	20.7%

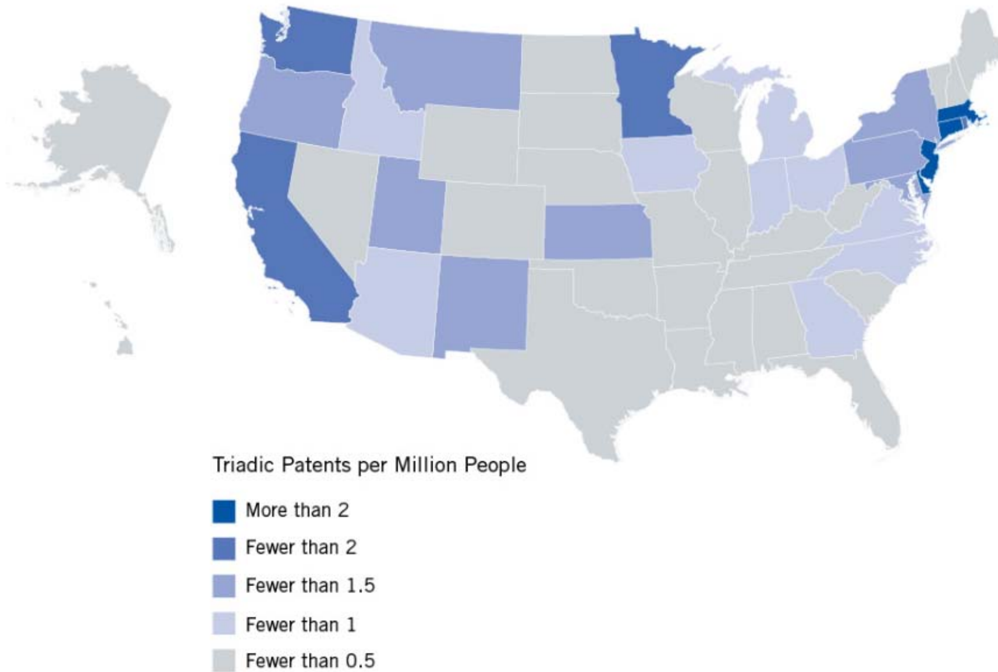
Of the samples, R&D 100 Award winners were by far the most likely to come from public institutions, with 50.5 percent coming from government organizations, research labs, or universities. This may reflect a greater interest among government labs to apply for consideration of the award. Only among R&D 100 Awards do privately owned companies make up a larger share of institutions than do publicly traded companies. Triadic patent samples, on the other hand, tend to come predominately from publicly traded companies. Among innovations from the patents' samples, life sciences patents had the most come from public sources, and had the highest concentration of university innovation at 16 percent, reflecting the importance of scientific breakthroughs to life sciences innovation. Materials sciences and information technology patents are more concentrated among publicly traded companies.

Innovation Location

Innovations in the sample were made in multiple locations across the United States, but followed some patterns.[95] California is home to the most overall innovations, with 22.7 percent of total life sciences, materials sciences, and information technology triadic patents and 19.8 percent of R&D 100 Awards. Most of these innovations occurred in the San Francisco Bay/Silicon Valley region, though San Diego also proved to be a major hub of innovation activity. Because large tech company innovations are nonrandomly distributed, we exclude them from this analysis.

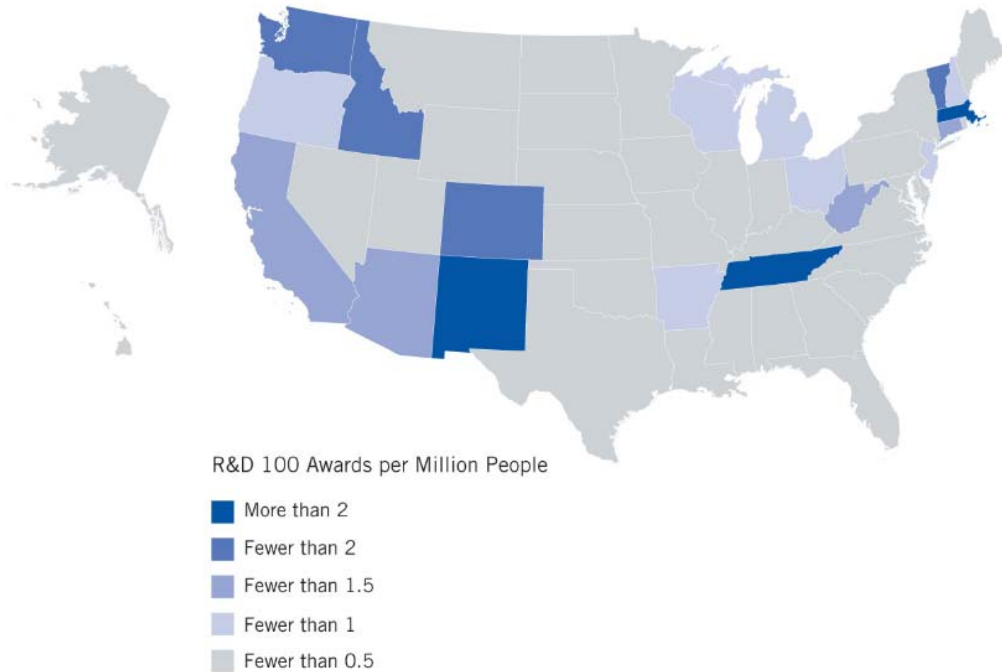
On a per-capita basis, Northeastern states led in the concentration of triadic patents, with Massachusetts, Connecticut, Delaware, New Jersey, and Rhode Island, in that order, comprising the top five states. Massachusetts had three triadic patents per million inhabitants, over four times the national average. Pacific-coast states Washington, California, and Oregon were also home to high concentrations of triadic patents, with Minnesota and Maryland rounding out the top 10.

Figure 23: Life Sciences, Materials Sciences, and Information Technology Triadic Patents with Responding Innovators per Million People, by State



R&D 100 Award-winning innovations cluster largely around strong universities and government research labs. Berkeley, home to California's preeminent public research university, had 8 out of the 202 R&D 100 Awards for which a respondent provided a location. The Los Alamos and Sandia National Laboratories in New Mexico, along with nearby Albuquerque and Santa Fe, accounted for 13 R&D 100 Awards; Oak Ridge National Laboratory and nearby Knoxville, Tennessee, had 12; and Cambridge, Massachusetts, home to MIT and Harvard, and surrounding Boston had 9. Concentration among awards may imply a selection bias among R&D 100 Awards, as certain institutions may prioritize applying for and receiving awards.

Figure 24: R&D 100 Award-Winning Innovations with Responding Innovators per Million People, by State



With 14 total R&D 100 Awards, New Mexico had by far the highest concentration of R&D 100 Award-winning innovations when controlling by population, with 10 times the national average of awards per capita at 7.7 awards per million people. Massachusetts and Tennessee finished second and third, with 3.8 awards per million people and 2.5 awards per million people, respectively. Washington, Idaho, Colorado, and Vermont also performed well on this metric.

Meanwhile, 10 states had neither an R&D 100 Award nor a Triadic Patent in the sample, including Alaska, Hawaii, Kentucky, Maine, Nebraska, Nevada, North Dakota, South Dakota, and Wyoming.

Surprisingly, the concentration of R&D 100 Awards per capita and the concentration of triadic patents in life sciences, materials sciences, and information technology per capita by state are only loosely correlated, with a correlation strength of 0.19. This is likely partly due to low sample sizes for many states, but also may reflect a stronger interest by public institutions in applying for R&D 100 Award consideration.

Table 27: Correlations by State between Concentration of Innovations and Public and Industry R&D Investment Intensity[96]

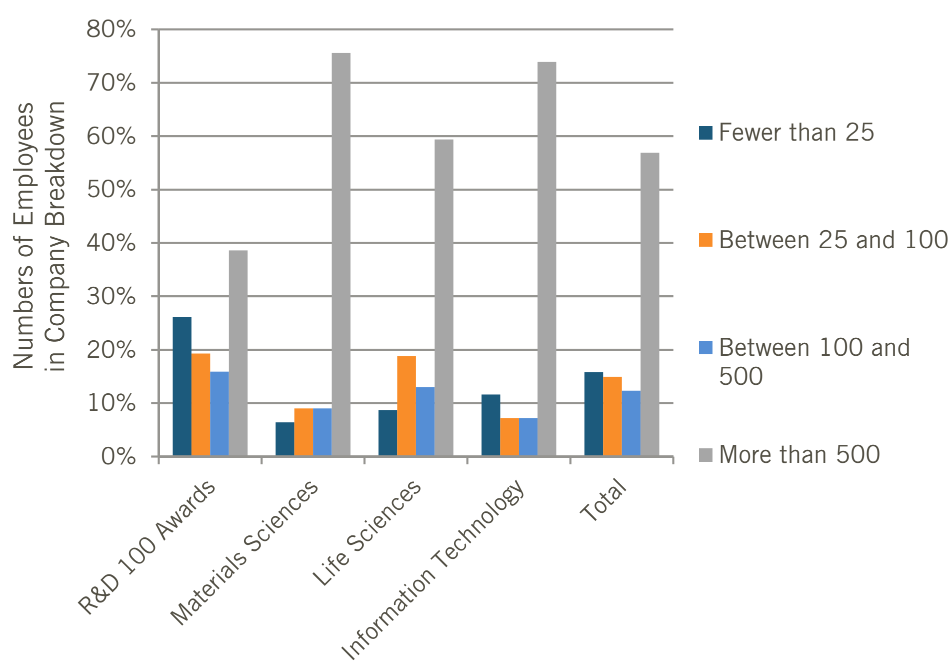
Correlations	Public Funding of R&D	Industry R&D
Triadic Patent Location	0.02	0.65
R&D 100 Awards Locations	0.71	0.19

By contrast, the concentration of R&D 100 Awards is highly correlated with the amount of public funding of R&D per state as a percentage of Gross State Product (GSP), with a correlation of 0.71. Similarly, the concentration of triadic patents bore a 0.65 correlation with industry R&D expressed as a percentage of worker earnings.[97] Conversely, the location of triadic patents filed had almost no correlation with publicly funded R&D, but this may be because federal labs are often in states that are not hubs for high-tech companies, such as Tennessee and New Mexico. Meanwhile, R&D 100 Award concentration had a weak (0.19) correlation with private R&D expenditures.[98]

Company Size

There has been a long-standing debate in the innovation policy community about which are more important to innovation: large or small firms. Large firms have the advantage of scale and scope. Small firms have the advantage of flexibility and a stronger desire to disrupt established industries. We polled respondents about the size of the companies employing them to gain a better idea of the firm size distribution. Because results for the large tech company sample are nonrandom in this context, we exclude those results from this sample.

Figure 25: Innovating Company Size Distribution, by Number of Employees[99]



In our sample, excluding the large tech company sample, 56.9 percent of innovations with responses were from large companies with more than 500 employees. However, there were large differences between samples. R&D 100 Award winners were much smaller, with only 38.6 percent of innovations coming from companies with more than 500 employees. Approximately 75 percent of materials sciences and information technology patents were filed by large companies, which reflects the capital-intensive nature of innovation in this field. By comparison, only 60 percent of life sciences patents came from companies with more than 500 employees, which reflects the relatively greater importance of innovation coming from smaller firms, many of which relied on technology advances at universities. Firms with fewer than 100 employees account for 27.5 percent of innovations in the life sciences patents' sample.[100]

Countering the popular narrative today that large firms are sluggish copiers and small firms the true innovators, firms with 500 or fewer workers in this sample make up only 43.1 percent of innovations.

Countering the popular narrative today that large firms are sluggish copiers and small firms the true innovators, small or medium-sized firms (SMEs) with 500 or fewer workers in this sample make up only 43.1 percent of innovations. This statistic matches well with the overall distribution of firms in the U.S. economy, where SMEs employ 48.4 percent of workers.[101] Of manufacturing firms in the overall economy, 45.5 percent are SMEs, and of technology firms only 27.5 percent of workers are employed by companies with under 500 workers.[102] Again, this matches the concentration in large firms seen in the information technology patent samples.

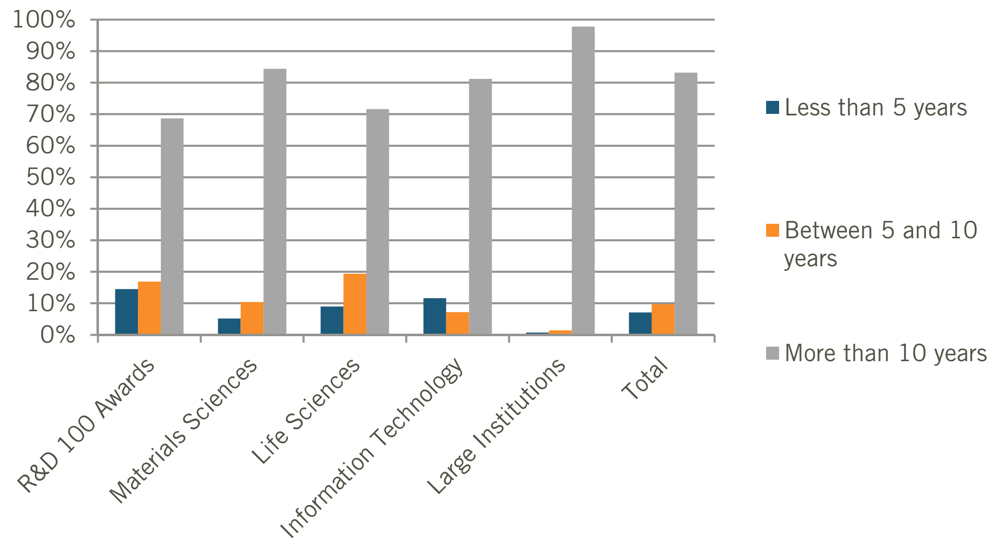
Information technology triadic patents are likely to come from either very large or very small firms, in line with the tech startup narrative. The innovations demonstrated through the R&D 100 Awards show a more equitable distribution of company size, with 26.1 percent coming out of very small firms, and 38.6 percent developed through large firms. Thus, R&D 100 Award-winning innovations seem to emerge out of a diverse range of firm types, contrary to inventions from the materials, life sciences, and information technology fields.

Workers in small firms with fewer than 25 employees are less likely to have been born abroad, with only a quarter of innovators at small firms born abroad.[103]

Company Age

Older companies may have more experience with developing innovation or have an established research and development system that fosters innovation. However, younger companies may be less constrained by the problem of disrupting existing internal business models, or may have been founded around an innovative idea, technology, or business model.

Figure 26: Company Age Distribution of Innovations, by Sample[104]



The length of time a company has existed mirrors company size for the respective sample groups. In our sample, about 75 percent of innovations in the R&D 100 Awards and subject field patent samples come from firms that have existed for over 10 years. Of particular interest, 11.6 percent of firms filing information technology patents have existed for less than five years. R&D 100 Award-winning innovations have 14.5 percent of innovations produced by firms less than five years old. R&D 100 Award-winning innovations also have the smallest proportion of inventions coming out of firms more than 10 years old, compared with the other samples.

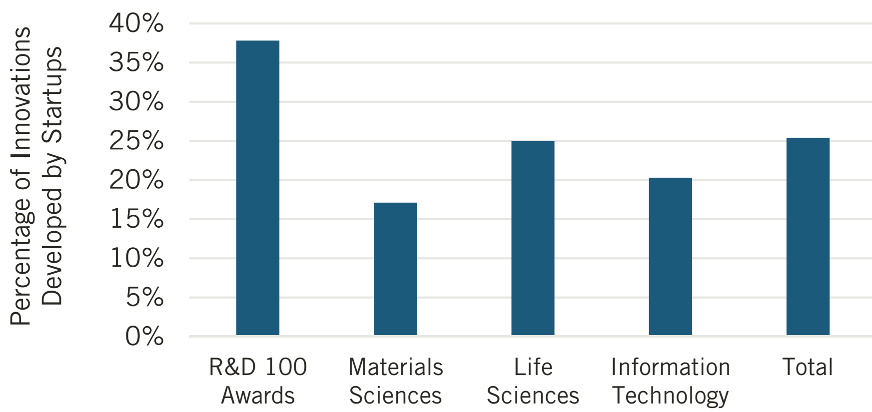
These numbers from small firms exceed employment totals in the overall economy. While 25.3 percent of innovations come from businesses that have existed for less than 10 years, companies under 10 years old employ 19.1 percent of the U.S. workforce.[105] Interestingly, in the United States there are more people employed by companies less than five years old than by companies between 6 and 10 years, in part because many of the former companies go out of business before they get to be 10 years old.[106] The opposite is true in our sample, where more innovating firms are between 6 and 10 years of age than are between 0 and 5 years of age. This may be because the gestation period for highly innovative companies is higher than average, meaning a startup or other young, innovative firm has a longer period to create an innovation, or it may simply represent survivor bias.

Startup Ventures

Entrepreneurial startups hold a unique mystique in the United States, where risk-taking and an inventive spirit have historical roots. Innovation today embraces a startup culture, which Silicon Valley symbolizes and embodies, especially in technology-intensive fields. Startups play a key role in allowing individuals to take larger risks with their ideas, and strong entrepreneurial policies can support startups and maximize the chance that their ideas come to fruition. Thus, it useful to understand to what extent startups contribute to this innovation sample.

In our sample, startups are not necessarily very small or very young firms. Rather, the survey asked respondents whether or not they considered their company to be a startup. Of firms with fewer than 25 workers, 81.8 percent identified as startups. However, only 48.6 percent of startups belonged in this category. Similarly, while startups tend to be young, 29.7 percent of self-responding startups were older than 10 years old. It seems that many innovators want to identify their company as a startup, even if the company is older or larger or has graduated from the startup stage of development. Respondents may also be indicating that their firm began as a startup company.

Figure 27: Percent of Innovations Developed Through a Startup Venture, by Sample



Looking solely at innovations produced by private firms or as a result of a public-private partnership, 14.9 percent reported some form of public grants.

Thirty-eight percent of innovations from the R&D 100 Awards were created through self-identified startup ventures, corresponding to the greater percentage of young, small companies in this sample. Subject field patents had lower rates of startup activity, averaging about 20 percent of patents. Among patents, life sciences patents had more startups, while materials sciences had fewer.

Government Funding

Research and development is a risky investment with significant spillovers to other firms. This is why economists have consistently found that, absent government-supported innovation incentives (e.g., research grants, R&D tax incentives, prizes, etc.), businesses underinvest in R&D relative to socially optimal levels.[107] It is in the public interest for government to provide support for R&D. Government funding has played a significant role in the development of groundbreaking innovations, both through funding basic research that forms the foundation for subsequent innovation and through encouraging and enabling private sector R&D through grants and incentives.[108] Identifying how many innovations have received public support allows a rough gauge on the importance of government assistance in developing innovation. We did not ask respondents if their firm used the R&D tax credit, but we did ask if they received any government grants.

Looking solely at innovations produced by private firms or as a result of a public-private partnership, 14.9 percent reported some form of public grants. Among the winners of

R&D 100 Awards, which come from a diverse range of technological fields, 44.2 percent of innovations received public grant support. By comparison, only 5.7 percent of large tech company innovations received support from public grants. Among patent filers, those in life sciences and information technology fields were more likely to have received public grants for research, while those in the materials sciences field were the least likely.

Table 28: Percentage of non-University and non-Public Research Institute Innovations Awarded Public Grants, by Sample

Sample	No Public Grants	One Public Grant	More Than One Public Grant	Public Grants per Innovation
R&D 100 Awards	55.8%	31.4%	12.8%	0.61
Materials	94.7%	2.7%	2.7%	0.09
Life Sciences	89.2%	6.2%	4.6%	0.16
Information Technology	88.6%	10.0%	1.4%	0.13
Large Tech Companies	94.3%	5.7%	0.0%	0.06
Total	85.1%	11.0%	3.9%	0.20

The Small Business Innovation Research (SBIR) program, which takes funds from the 12 federal agencies with R&D budgets, such as the Department of Defense, the Department of Energy, and the National Science Foundation, gives the most grants to innovating firms, distributing 25.5 percent of the total grants received by innovators.[109] In total, 5.1 percent of private innovations were supported by SBIR grants.

Non-SBIR grants from the Department of Energy and the Department of Defense also had broad impacts on innovation, constituting 23.6 percent and 17 percent of total public grants to private innovators, respectively.

Table 29: Percent of non-University and non-Public Research Institute Innovations in Each Sample Receiving a Public Grant by Grant-Giving Agency

Sample	Department of Defense	Department of Energy	National Institute of Health	SBIR	State Government	Other
R&D 100 Awards	12.0%	17.6%	1.8%	15.7%	5.6%	8.3%
Materials Science	0.0%	2.3%	1.1%	3.4%	0.0%	2.3%
Life Sciences	1.3%	2.7%	2.7%	5.3%	0.0%	4.0%
Information Technology	1.3%	1.3%	1.3%	2.6%	1.3%	5.2%
Large Tech Companies	1.8%	0.6%	0.6%	0.6%	0.0%	2.4%
Total	3.4%	4.7%	1.3%	5.1%	1.3%	4.2%

When asked to elaborate on "Other" responses, innovators cited receiving support from institutions such as the National Air and Space Administration, National Institute of Standards and Technology, National Oceanic and Atmospheric Administration, and the Environmental Protection Agency, among others.

Interestingly, given their much smaller budgets than the federal government, state government provided 6.6 percent of grants supporting innovations, while the federal government provided the remaining 93.4 percent.

SBIR grants are particularly important in the size category they represent. Of the 40 innovations in the sample created by private firms with fewer than 25 employees, 18, or 45 percent, received SBIR grants. Sixty percent of firms with fewer than 25 employees received some form of grant. Additionally, of private firms with between 25 and 100 employees, 17.1 percent received SBIR grants, and 34.2 percent received some form of grant.[110] Both of these totals are much higher than the overall average of 14.9 percent of all private innovations with grants.

Interestingly, given their much smaller budgets than the federal government, state government provided 6.6 percent of grants supporting innovations, while the federal government provided the remaining 93.4 percent.

Importantly, startups received over half of public research grants despite consisting of less than one-fifth of private firms with innovations in the sample. In total, 42.3 percent of startups received some form of public grant, compared with 10 percent among other private companies.

Table 30: Percent of Startups and Non-Startups Receiving Public Grants by Sample

Sample	Private Innovations Receiving SBIR Grants	Private Innovations Receiving at Least One Public Grant
More than 500 Employees	0.3%	7.4%
Between 100 and 500 Employees	0.0%	22.9%
Between 25 and 99 Employees	17.5%	35.0%
Fewer than 25 Employees	42.9%	59.5%

R&D 100 Award-winners received the most government grants, but grants are also common among startups filing triadic patents. Startups face a "valley of death" between the R&D and commercialization phases of business development, in which capital is needed to prove an unproven product, but in which investors are unwilling to take chances on the product because it is unproven. Public grants help bridge that valley.

Collaboration

As scientific knowledge becomes more specialized, collaboration between institutions allows innovators to tap into one another's expertise in order to develop a successful product. Out of 572 innovations with responses, 113, or 19.8 percent, were collaborations between two or more institutions.

Table 31: Distribution of Innovations Created Through Collaborative Efforts, by Sample[111]

Sample	Collaborative Innovation	Non-Collaborative Innovation
R&D 100 Awards	49.7%	50.3%
Materials Sciences	10.3%	89.7%
Life Sciences	15.6%	84.4%
Information Technology	2.7%	97.3%
Large Tech Companies	2.0%	98.0%
Total	19.8%	80.2%

Collaborations occur the most in R&D 100 Award-winning innovations. In fact, almost half of R&D 100 Award-winning innovations were the result of collaborations. This implies that more groundbreaking innovations, those cited as being among the most influential of the year, are likely to require diverse institutions working together. We see lower levels of collaboration among triadic patents, especially among information technology and large tech company patents.

Table 32: Number of Collaborative Innovations by Innovating Institutions, by Sample

Sample	Public-Private Partnerships	Public-Public Partnerships	Private-Private Partnerships	Other
R&D 100 Awards	45	16	11	14
Materials Sciences	5	1	3	0
Life Sciences	5	1	5	4
Information Technology	1	0	0	1
Large Tech Companies	1	0	1	1
Total	57	18	20	20

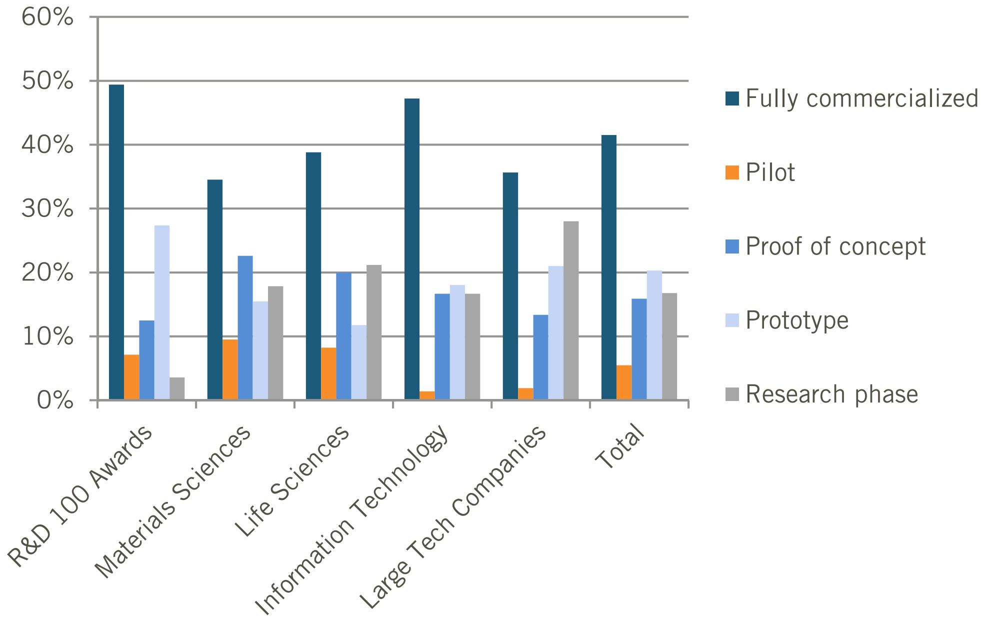
Half of collaborations include both a public and private partner. Of these, 36.8 percent were partnerships between a university and a private firm, 52.6 percent involved collaboration between a government organization or public research institution and a private firm, and the remaining 10.5 percent were collaborations among all three.

Additionally, 15.7 percent of collaborations were among multiple public institutions, including universities and government organizations. These are especially prevalent among R&D 100 Award-winning innovations, while relatively rare among triadic patents. Other collaborations comprise 17.4 percent of collaborations, mostly involving nonprofit research institutions, self-employed innovators, or other institutions.

Commercialization

Ultimately, commercialized innovations represent a means to validate the success of the innovation process. The innovation pipeline from start to end takes years, and some innovations, including many innovations in our sample, do not reach the end. Commercialization status provides a gauge for determining how many innovations eventually succeed in the marketplace.

Figure 28: Commercialization Status of Innovations, by Sample



Of the innovations in our sample, 46.1 percent are fully commercialized. R&D 100 Award-winning innovations have the highest rates of full commercialization at 49.4 percent, in part because of the competitive process used to select R&D 100 Award winners. Only a small proportion of R&D 100 Award-winning innovations, 3.6 percent, were still in the research phase.[112]

Of course, our samples aim to identify innovations with commercial potential, so it isn't surprising that a high number of innovations in the sample have been commercialized. Theoretically, many of the patents filed are on their way to commercial status. For R&D 100 Awards, commercial status is a prerequisite. But what is concerning is any factors that prevent or delay the commercialization of innovations with considerable market potential.

Innovators report the most significant barriers that slowed or prevented the commercialization of their innovations and were asked to list a first, second, and third most significant barrier. Innovators for 27.8 percent of innovations (159 out of 572 innovations) report that their innovation faced barriers to commercialization.[113] That over one-quarter of innovations were deemed to face barriers to commercialization shows that even with a promising innovation, the path to market is not always clear. It also suggests ways that thoughtful public policies can better help innovators successfully navigate these challenges.

Table 33: Barriers to Innovation, Total Counts, and as a Percentage of Innovations

Barriers to Innovation	Listed as Barrier (Most Significant/2nd Most/3rd Most)	Percentage of Innovations with Listed Barriers
Company unwilling to bring to market	39 (18/10/11)	24.5%
Competition from other innovators	66 (21/29/16)	41.5%
Insufficient market demand	81 (35/37/9)	50.9%
Lack of funding for further development	92 (59/19/14)	57.9%
Regulatory challenges	53 (18/25/10)	33.3%
Technical infeasibility of the innovation	63 (39/16/8)	39.6%

Almost 10 percent of innovators listed regulatory barriers to commercialization, and one-third of those identifying barriers cited regulatory barriers.

Innovators find that lack of funding for further development is the largest and most prevalent barrier they currently face, with 92 total mentions, 59 of which list it as the most significant barrier. All told, lack of funding is cited as an issue for 16 percent of total innovations and for over half of innovations for which barriers to commercialization were reported. Technical infeasibility of the innovation received the second most responses as the most significant barrier, affecting 14 percent of innovations, while insufficient market demand affected 11 percent. Interestingly, almost 10 percent of innovators listed regulatory barriers to commercialization, and one-third of those identifying barriers cited regulatory barriers. These survey results identify that both supply side and demand side barriers can have a negative impact on the commercialization of innovations.

On average, 60.8 percent of the inventions in our sample earned less than $25 million in total revenue across the lifetime of the innovation, while 7.7 percent made over $500 million.[114] Of the 10 innovations that made over $500 million, half are patents from the information technology field. Most of the innovations from the R&D 100 sample have less than $25 million in revenue. Materials sciences patent innovations are likely to fall in the $100 million to $500 million revenue range. Interestingly, given the high costs of drug development and considerable technical and regulatory uncertainties, only 21 percent of life sciences innovations have generated more than $100 million in revenue.

Table 34: Total Revenue Generated from Commercialized Innovations by Sample[115]

Sample	Less than $25 Million	Between $25 Million and $100 Million	Between $100 Million and $500 Million	Greater than $500 Million
R&D 100 Awards	73.7%	15.8%	8.8%	1.8%
Materials	52.9%	29.4%	17.6%	0.0%
Life Sciences	42.9%	35.7%	7.1%	14.3%
Information Technology	42.9%	23.8%	9.5%	23.8%
Large Tech Companies	61.9%	14.3%	14.3%	9.5%
Total	60.8%	20.8%	10.8%	7.7%

Among innovations with respondents, startup-led innovations have a greater likelihood to be fully commercialized than other innovations and are much less likely to still be in the research phase. Only 6.8 percent of startups report that their innovation is in its research phase, compared with 22.5 percent among non-startup firms.[116] Instead, 9.4 percent of startups report that their innovation is currently in a pilot program, compared with 3.8 percent of other firms.

IMPLICATIONS FOR INNOVATION POLICY

The findings here suggest two important policy implications related to STEM talent in the U.S. economy.

The United States should focus intensely on expanding the supply of potential innovators, both by letting in more high-skill, STEM-educated immigrants and by increasing the pool of highly educated scientists and engineers, particularly women and minorities.

The first is to do a better job enabling women and minorities to gain STEM degrees. This will require more effort at the K-8 level, and, particularly, as ITIF has noted in the past, at the high-school and college levels. Policymakers should consider expanding STEM high schools, particularly in disadvantaged communities, and expanding and improving computer science and engineering education in all American high schools. The country also needs stronger incentives for colleges and universities to do a better job of retaining students with an interest in STEM, as well as more funding for Ph.D. fellowships.

Second, given the importance of foreign-born STEM workers to American innovation success, we need policies to strengthen and expand the immigration pipeline that allows highly trained STEM workers to innovate in the United States, including foreign STEM graduates of U.S. colleges and universities who often have a hard time staying legally. ITIF has provided more detailed policy recommendations in other reports.[117]

CONCLUSION

For the United States to continue to lead the world, it must reassert itself as a leader in innovation. The results of this survey illustrate who in the United States innovates. We find that different segments of the population innovate at vastly different rates, that in-depth, specialized knowledge and experience in science, technology, engineering, and mathematics is vital to innovation, and that government has a real role to play in both conducting research and fostering innovation.

One major factor holding the United States back in this regard is the lack of an adequate workforce in STEM fields. To improve U.S. productivity, innovation, and competitiveness, the United States should focus intensely on expanding the supply of potential innovators, both by letting in more high-skill, STEM-educated immigrants and by increasing the pool of highly educated scientists and engineers, particularly women and minorities.

APPENDIX A: METHODOLOGY CONSIDERATION WITH R&D 100 DATA

The self-selection criteria that generate the R&D 100 Awards data set create an opportunistic sample, which allows us to easily identify highly valuable innovations. Because the award requires an application, applicants incur a non-zero economic cost, which creates a barrier of entry for less "inventive" innovations. Furthermore, a team of judges helps screen for the most innovative products to include on the final winners' list.

Although this double-screening process results in a robust sample of 100 recognizably innovative products a year, certain inherent biases remain in the sample. Importantly, the selection criteria tilt favorably toward product innovations rather than innovations designed to raise the efficiency of production processes for goods and services. Some process innovations, such as a new type of machine tool or a more advanced computer program for managing inventories, might be recognized, but many important process innovations that involve complex combinations of new equipment and new organizational practices are likely excluded from consideration.

In addition, the R&D 100 Awards are biased in favor of "cool gizmos" rather than recognizing less flashy innovations that may have a broader market impact. R&D professionals may value or put emphasis on certain criteria that could result in a biased evaluation. Other biases might also affect the R&D 100 Awards' selection process. Questionable decisions and politics will always be a factor, as jury members could theoretically reward friends and deny recognition to competitors. However, the R&D 100 Awards still represent 100 highly valuable innovations, even if they are not, objectively, the most influential innovations of the year.

Finally, it is difficult to imagine any reason that *R&D Magazine* and the juries involved would prefer submissions that originated in public labs over those from private labs, or vice versa. The criterion that the product actually is available for sale is a great equalizer; it means that the awards are not recognizing abstract ideas but saleable products.

APPENDIX B: METHODOLOGY CONSIDERATION WITH PATENT DATA

Patent data have been used widely for many years to measure innovation. Databases incorporate variables such as previous authorship, size of the team listed on the patent, and specialization (through testing whether additional patents were cross-listed in other fields). This data allows an in-depth look at the nature of innovation.

However, regular patent data has well-documented shortcomings. While patents are easily organized and contain scalable data sets consistent across countries, they reflect only certain types of innovation. Moreover, patents tend to vary greatly in quality. Patents filed through the U.S. Patent and Trademark Office (USPTO) may be market-applicable results of intensive R&D activity, but also may be filed for prestige, for minor innovations or inventions, or even by patent "trolls" for use in spurious lawsuits.[118]

For this study, we chose to use triadic patent data to measure innovation, since triadic patents have several inherent advantages over USPTO patents. First, due to the higher costs associated with triadic patent filing, these patents are likely to be of higher economic value and represent greater innovations. Triadic patent filers must pay fees in three patent offices, essentially tripling costs. Additional legal fees can contribute to higher costs for triadic patents. Second, triadic patents are much more likely to be used for protecting a commercialized good that adds value to the global economy. This eliminates much of the discussion about quality of patents versus the quantity. Third, triadic patents tend to exclude patents filed for academic posterity (to receive the honorific of "patent holder"), "troll" patents filed not with commercialization in mind but to cash in on innovations down the road, and low-innovation patents that will have little impact on the global economy. Finally, triadic patent families group together very similar patents to avoid double counting.

In essence, triadic patents can be used as a better indicator for not just who is filing patents, but who is creating the most valuable innovations in advanced fields.

Legally, the names of innovators listed on triadic patents must be individuals who made real contributions to the innovation. In the United States, an invention is defined as having two parts: conception and reduction to practice, or the process of showing how the invention is used to achieve its purpose. To be considered as an inventor and listed on a triadic patent, an individual must have made an inventive contribution to the "conception" of the innovation.

In 2012, Americans filed over 13,700 triadic patent families, down by 12 percent since 2000 and representing 26.5 percent of the world's total triadic patent families.[119] This allows a large, robust data set. By comparison, in 2012 there were 268,800 utility patents of U.S. origin filed with the USPTO, meaning that triadic patents represent a selective 5.1 percent of patents.[120]

The small number of patents that are filed as triadic patents provides a screening barrier for lower-value patents, but could also potentially serve as a barrier against innovations from small or young firms.

Our sample draws from a data set managed by the Organization for Economic Cooperation and Development (OECD), which is available to all upon request. This data set is used mostly to track progress in specific fields or to compare countries internationally. The patents list the names of inventors, who can then be contacted. The sample draws an equal number of patents from four years and across the three technology fields: life sciences, materials sciences, and information technology. These categories are constructed from multiple, more narrow categories in the OECD database, as shown below.[121]

Table 35: Subcategories for Triadic Patent Subject Field Classifications[122]

Triadic Patent Technology Category	OECD Classification
Life Sciences	Medical technology; Biotechnology; Pharmaceuticals
Materials Sciences	Macromolecular chemistry, polymers; Basic materials chemistry; Materials, metallurgy; Micro-structure and nanotechnology
Information Technology	Audio-visual technology; Telecommunications; Semiconductors

Because triadic patents are frequently used as a measure of innovation, knowledge diffusion, and success of R&D internationally, there is ample discourse on the robustness of this data in the existing literature. Triadic patents are deemed to represent more valuable innovations, and are used as instruments for the total value of innovations produced by a country. Lanjouw and Schankerman, while developing an index to proxy the quality of individual patents, found that there is strong evidence that "the decision to take a patent out abroad" signals an innovation's greater intrinsic value.[123]

Dernis and Kahn find that patent counts taken from individual patent offices include a home country bias.[124] Inventors usually file for protection in their home country first, so the majority of patents at the USPTO, European Patent Office, and Japanese Patent Office are from domestic inventors. Thus, counts of patents from a single patent office do not provide an accurate comparison of the level of inventive activity across countries. However, because we use triadic patents only as an indication of U.S. innovation and do not compare directly with other countries, this shortcoming does not affect our study.

Country-specific studies have used triadic patent data to explore innovators' demographic characteristics in South Korea and Sweden, and the PatVal-EU survey analyzed innovation in Europe in the 1990s.[125]

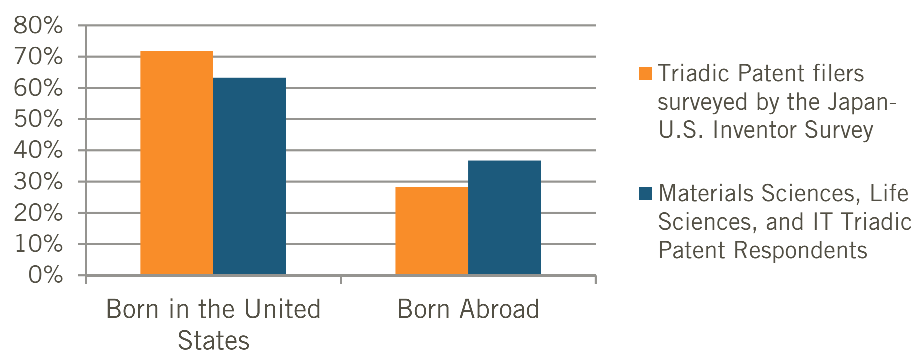
In an examination of patent data quality, David Popp wrote, "The results of studies using patent data are best interpreted as the effect of an 'average' patent, rather than any specific invention. Alternatively, other information about the patent, such as subsequent patent citations or the family size, can be used to weight individual patents and control for quality differences."[126] In our study, we sample broadly to gain a general idea of the population of innovators filing the "average" triadic patents. However, this study chooses not to weigh patents based on factors that attempt to predict patent quality employed in other research, preferring to sample and then view each innovator's contribution as equal. This avoids making too many assumptions and allows our data to be used to draw simple comparisons to other samples as well as to the population at large.

Comparing Results to Previous Work: Walsh and Nagaoka

The last major attempt to use triadic patent data to examine U.S. innovators was Walsh and Nagaoka, who sampled over 1,900 patented innovations from U.S. inventors (at a 24 percent response rate) and compared inventors in the United States and inventors in Japan.[127] The paper sought to give a better understanding of the demographics, motivations, and career trajectories of inventors in the two countries.[128] The paper credits the international aspect of triadic patents as working as a threshold that keeps low-value patents out of the sample and ensures that only patents on the higher end of the economic value spectrum are included.

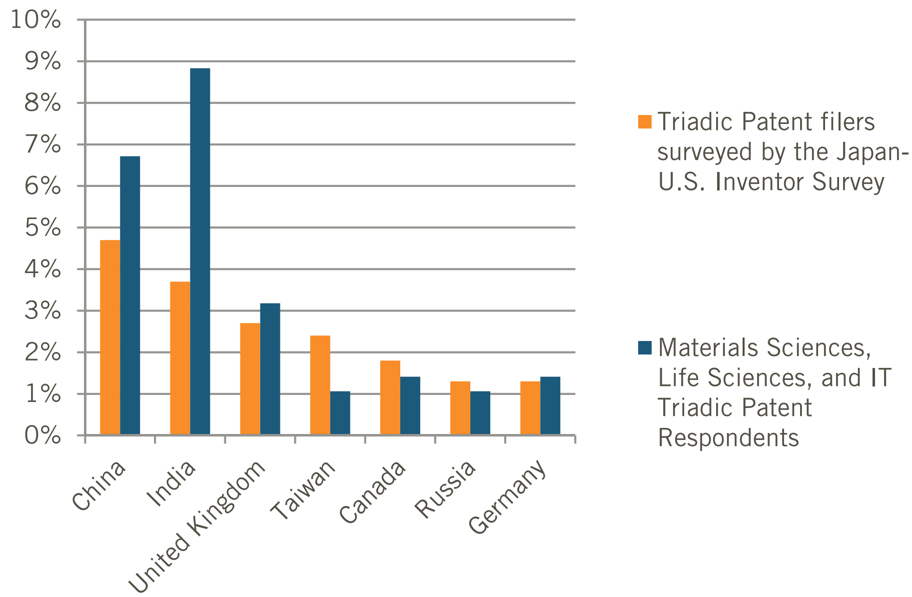
This survey found that 35.5 percent of the overall sample, and 36.7 percent of the triadic patents in life sciences, materials sciences, and information technology were filed by immigrants. This figure is significantly larger than the finding of "Who Invents?: Evidence from the Japan-U.S. inventor survey," by Walsh and Sadao, the most similar study to our own, based on the RIETI survey of triadic patent holders. Walsh and Nagaoka find that only 28.2 percent of triadic patents holders responding to their survey were born abroad, 8.55 percentage points fewer than the comparable sample in our survey.

Figure 29: Innovators Born Abroad and in the United States



What explains the difference in results? There were several methodological differences in the two studies. First, our results include innovators active between 2011 and 2014, while the RIETI survey polled innovators between 2000 and 2003. They also sampled only the first U.S.-based innovator listed on the patents, instead of surveying all innovators listed as contributors on the patent. Finally, the RIETI survey included all subject fields, while ours identified three areas of interest.

Figure 30: Percentage of Responding Innovator, by Foreign Country of Origin



The above seven countries represent roughly 64 percent of all foreign-born innovators across the two samples. Most of the difference comes from innovators from China, India, and Taiwan. It is possible that innovators from these countries have become more numerous in the decade spanning the two studies, or that they are less likely to be listed as the lead innovator on a triadic patent, or that they are simply more common among innovators in the subjects our study isolated.

APPENDIX C: METHODOLOGY OF LARGE ADVANCED TECHNOLOGY COMPANY TRIADIC PATENTS

The large advanced technology companies' triadic patent sample deviates from the methodology used to collect life sciences, materials sciences, and information technology triadic patent sample contact information. Innovations were drawn from prolific American patent filing companies.[129] Names of innovators listed on these innovations were then inserted into known typical email formats for these institutions.

Companies were selected from firms filing large numbers of patents, all of which were in the top 20 of most prolific individual patent filers. Then, we took all innovations the company had applied for triadic patents for in the past 12 months. Rather than individually search for contact information for each innovator, we identified common email formats for each company. Then we inserted names of patent filers into this format.

This approach proved successful for four out of the seven firms we originally sampled. The other three were excluded from the sample based on very low response rates, due to incorrect or lack of common formats or detection by spam filters. In total, four firms yielded 2,564 innovators from 1,051 innovations.

Large tech company patent holders had a lower response rate as a percentage of emails sent. Many of the emails collected in this manner did not reach innovators, whether because of incorrect addresses or because of spam filters. A low response rate implies that only a small percentage of emails reached their destination, a hypothesis supported by high numbers of email returned marked as undeliverable.[130] We estimate that only around one-half of emails made it to their destination, leading to response rates lower than what we saw in other cases.

There may be patterns within individual institutions regarding which employees have standard, guessable email addresses or which employees have stricter spam filters, whether skewed by department, by hierarchical level, or skewed against individuals with common names who use secondary or tertiary corporate email formats because the first option was already taken. Because of this, there is a possibility of a sampling bias against some individuals.

Polling large tech companies complements the rest of the triadic patent sample, however, which has an observed selection bias against large firms due to the relative difficulty in finding valid email addresses for these innovators. Furthermore, the large tech company patents' sample follows many similar biases to the overall sample and serves as a useful comparison point to the demographic profiles of those at smaller companies, those filing patents in specific fields, and winners of R&D 100 Awards.

The large tech companies' triadic results contrasted sharply with the rest of the samples. As noted, respondents were significantly younger, had fewer advanced degrees (especially Ph.Ds.), predominately held undergraduate degrees in engineering, and were more likely to be male. This, however, is unlikely a result of the different sampling method or evidence of a strong sampling bias among the other samples. Our hypothesis is that large tech companies' R&D that leads to innovations is more applied than many of the patents in specific fields or the R&D 100 Awards. Hence, we would expect innovators to have fewer years of advanced education and be younger in age.

APPENDIX D: DATA COLLECTION METHODOLOGY

The following enumerates the steps undertaken to locate email contact information for the R&D 100 Award and subject patent samples:

1) Verify the researcher's current affiliation using LinkedIn, Researchgate, Google Scholar, and organizational websites such as Lawrence Livermore National Laboratory.[131]

2) Search the organizational website for biographical or contact pages that contain email addresses. The easiest way to do this is with a search engine: Search for researcher name and organizational website domain (if known). If the organization's website URL is unknown, search for the name of the organization. Using quotes around the name will improve the search results, but only if the name is spelled correctly. For example, for an innovator named John Doe known to work at George Mason University, Google: "John Doe" site:gmu.edu or "John Doe" George Mason University.

3) If there are no positive results, verify the spelling of the name and organization. A few of the names were misspelled in the original source (especially from the R&D Award website), so look for possible alternative spellings. Also, some researchers go by a nickname or middle name, and others have changed their last names since winning the award or getting the patent. To broaden the search to alternative spellings, remove quotes from the search syntax. Google and many other search engines will automatically search for variations in a name, such as "Robert" and "Bob."

4) If there are no results on an organizational website, look for publications, presentations, online CVs/résumés, and posted correspondence (online copies of email conversations, etc.) that may contain an email address. Use a preponderance of evidence standard to verify the accuracy of any email addresses that may be listed. If more than one source lists the same address for what appears to be the same person, that address is probably valid. Also, try filetype:pdf in Google search for more targeted search for papers and CVs.

5) If the email address does not appear in any of the above searches, change the search approach. Rather than search for an email address, search for the person based on a best guess of what the address may be. This is most effective if one already has email addresses for others in the same organization. For example, if jdoe@gmu.edu is a verified address, then it is likely (but not certain) that an inventor named Abe Froman who also works at George Mason University will follow the same format: afroman@gmu.edu. If a search for afroman@gmu.edu includes results that link this address with the correct name (and affiliation), then the address is valid. If there is at least one deviation in format for a given organization, then this approach is not likely to work. Also try to search first and/or last name with email format in quotes; e.g. Abe Froman "@gmu.edu".

6) As a last resort, use technical verification methods:

    a. Search for the exchange server address using a Domain Name Service lookup. This can be accomplished by command line or using an automated email address verification service.[132]

    b. Connect to the exchange server (if possible) and conduct a mail from/receipt test using Telnet, a similar interface, or an automated verification service. Use the best estimated email address format, based on the methods from step 5.

    c. If the output of the test is a 550 or similar error, then the email address is not valid. If the output is "OK," then the address may be valid.

    d. Repeat the above steps using the next best estimated address format. If the output is an error but was previously "OK," then it is very likely that the previous address was valid. If it is an error and was previously an error, try again with a different address format. If it is "OK" and was previously an error, then the current address is very likely to be valid. If it is "OK" and was previously "OK," then this method will not be able to produce a result with high confidence.

APPENDIX E: NAMSOR TESTS AND INTERPRETATIONS

Onomastics studies the history and origin of names. For our study's purposes, NamSor API tools allow us to obtain a guess (with another guess estimating the probability of accuracy) for the gender and country of origin of each name in the sample.[133]

These estimates allow us to see whether there are observable biases in the gender or country in origin that affect the final sample. For instance, if the algorithm predicted that 12 percent of the subset of the sample of respondents were female, but estimated that 25 percent of the overall sample were female, we would conclude that for some reason the sample of respondents has a selection or response bias that favors males. Similar comparisons are possible with innovators hailing from specific countries. We also can test for biases inherent in our email collection methodology by comparing the subset of innovators that we successfully contacted with both the subset of responding innovators and the sample as a whole.

The second utility of this data is our ability to use the predictions to guess the gender and country or region of origin for each innovator in the sample regardless of response status. Because we know with certainty the gender and ethnicity of respondents, we could compare these data to the NamSor estimates to screen for the accuracy of the entire sample. For gender, this allowed us to create a guess for the percentage of NamSor guesses that were accurate, as well as the gender probabilities of innovators with names for which the NamSor algorithm was unable to generate predictions. For country of origin, it allowed us to get a good prediction for the likelihood that an individual was born in the United States based on a combination of the guess produced by NamSor and the survey responses.

Gender Predictions

Concerning gender, NamSor scores a name on a scale of negative one to positive one, with a negative score computed as male, and a positive score computed as female. Thus, a few names in our sample were indeterminate when NamSor returned a score of zero or close to zero. Guesses are based on both first and last name, so innovators with identical first names may be assigned different gender probabilities based upon the language of origin of their surname.

NamSor has the unique feature of recognizing names in various language scripts, such as Chinese, Japanese, Cyrillic characters, etc. However, all the names we extracted for the sample use the Latin alphabet. Thus in cases where gender characteristics depend on the non-Anglicized version of an inventor's name, the NamSor algorithm lacked the finesse to reveal such characteristics. We found this limitation especially with East Asian names, where due to data limitations, we were unable to exploit the capabilities of NamSor fully to provide us more precise evaluations. In fact, over 93 percent of innovators with names guessed as unknown were predicted by the Country of Origin API tool to belong in the Chinese language group.

To establish a gendered breakdown of our entire sample, we ran a logistic regression on the predictability of the known gender of the innovator gathered through the survey with the guessed gender score by NamSor and a binary variable on whether NamSor guessed right.

A logistic regression produces predicted probabilities, which provides us a means to statistically distribute the gender of our entire sample, through weighting an individual's real gender against their guessed gender. Through this method we can make claims at the 95 percent statistically significant level about what percentage of the guessed gender by NamSor likely predicted the correct gender.

Table 36: Whole Sample and Subset of Respondents by NamSor Gender API Guesses

***Excludes Unknown Responses**

NamSor Guess	Guesses For Sample	Percentage	Guesses for Respondents	Percentage	Percentage Accuracy among Responders
Male, Confident	6,812	69.7%	543	73.0%	97.6%
Male	787	8.1%	62	8.3%	93.5%
Unsure or Unknown	1,099	11.2%	57	7.7%	50.0%*
Female	211	2.2%	15	2.0%	80.0%
Female, Confident	863	8.8%	67	9.0%	80.6%

We were also able to compare NamSor's guesses for innovators who responded with actual responses. Our survey had 654 males and 90 females respond. The NamSor algorithm did a fairly good job of guessing the gender of males and females, though it was much more accurate for men than for women.

After deriving our predicted gender distribution for the entire sample, and correcting for accuracy, we tested the gender distribution of our respondent sample against the gender distribution of the entire sample (excluding individuals with unknown genders) through a Chi-Square test of independence. Chi-Square tests ascertain the statistical relationship between categorical variables, such as gender and ethnicity, variables that cannot be weighed along a number scale or ranked by importance. This test demonstrates if there is an association between the two variables, and in the case of gender, whether there is an association between the sample in question and the gender of the innovators.

A p-value of 0.19 from the Chi-Square test indicates that statistically, with 95 percent confidence, there is no association between gender and the samples. In other words, the predicted gender distributions over the entire samples and in the subset of respondents are similar enough to one another. If the p-value was below 0.05, it means that the difference in gender distribution was not entirely due to chance, but some underlying cause has resulted in a difference in gender proportions. Thus, such tests allow us to identify if there were sampling issues or methodological flaws that led to biased responses.

NamSor's gender predictions also allow the construction of a gender profile for each innovation's team. We estimate that approximately 719 innovations contained at least one female member as part of the team in our sample of 2,651 innovations, or a 27 percent representation.

Country of Origin and Language Families

The NamSor algorithm makes predictions based upon the sociolinguistic history and structure of a given first and last name. Naming conventions and patterns follow predictable trends associated with various languages and countries. The algorithm used gives predictions of country of birth, and provides a level of confidence that the prediction is correct.

Most names, however, are more readily associated with languages rather than individual countries. For instance, names commonly found in the United Kingdom are also common names in Ireland, the United States, Australia, South Africa, Ghana, and other countries where English is the primary language. Names in India are very similar to those found in Sri Lanka and Bangladesh.

To address ambiguity and difficulty deciphering between similar countries, the predicted countries in the sample are sorted into 24 language families based on common linguistic traditions. For instance, the Chinese language group encapsulates China, Hong Kong, Mongolia, and Taiwan. The Germanic language group includes names that the algorithm predicted originated in Germany, Austria, Switzerland, and Rwanda. Other language groups were smaller, depending on the relative uniqueness of naming conventions in each country. For instance, Romania, with a very distinctive language, is in its own family. Finland, Greece, Italy, Japan, the Netherlands, and Vietnam also each have a unique language family grouping.

This process, of course, tells us little about race or ethnicity, only country or region of origin. For instance, in most cases African American names are not broadly different in origin from Caucasian names.

In our survey, innovators responded with their country of origin, and their parents' country of origin. Much like in the Gender API results, we are able to compare guesses to actual responses for the subset of the sample who responded, allowing us to gauge the accuracy of the API's estimates and devise an appropriate method for interpreting guesses. By comparing those responses to the predicted linguistic origins of the responding innovators' names, we were able to predict the likelihood that an individual was born in the United States or born abroad. Using these predictions, we can produce a probability-based estimate of where each innovator was born based on these results.

Table 37: Percentage Probability of Innovator's Origin by Language Family

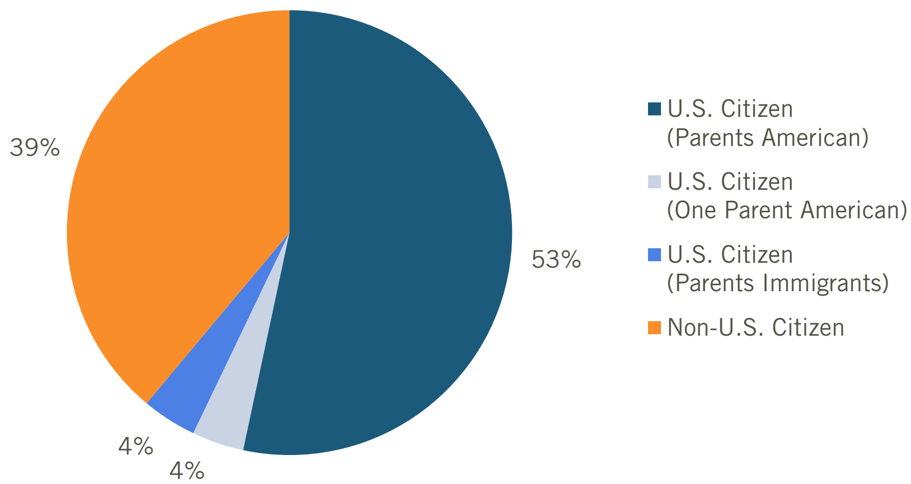
Language Family	Percentage of Sample	Likelihood U.S.-Born, Parents American	Likelihood U.S.-Born, 2nd Generation	Likelihood Foreign-Born
English	38.7%	76.4%	8.0%	15.6%
Germanic	11.0%	68.3%	7.3%	24.4%
Indic	8.1%	8.3%	10.0%	81.7%
French	7.5%	46.4%	12.5%	41.1%
Israel*	6.9%	68.6%	9.8%	21.6%
Other European	6.6%	49.0%	12.3%	38.8%
Chinese	6.6%	4.1%	2.0%	93.9%
Slavic	4.0%	30.0%	10.0%	60.0%
North Germanic	3.4%	84.0%	0.0%	16.0%
Other Middle-Eastern	3.0%	40.9%	4.5%	54.5%
Italian	2.3%	53.0%	5.9%	41.2%
Other Asian	2.0%	26.7%	0.0%	73.3%

English-origin names comprised the largest section of the sample, and of this group 84.4 percent were born in the United States. Other European-based language families had high percentages roughly in line with the average share of foreign-born innovators found in the sample (35.5 percent), with the exception of "Slavic," which is more skewed toward immigrants. By contrast, most names that the algorithm categorizes into the Chinese or Indic language groups were born abroad.

The NamSor algorithm categorized an oddly large number of innovators with the "Israel" language group. In essence, "Israel" functioned as a catchall for hard to categorize names. A low percentage of responding innovators were actually from Israel.

To test whether the responding innovators' number is an accurate representation of the overall population, once again a Chi-Square test examined association between sample and language group. The test analyzed three samples broken down by country of origin: respondents (actual country of origin), innovators with emails (predicted country of origin), and all innovators from our sample (predicted country of origin). Once again, a p-value of 0.13 suggests that a lack of statistical dissimilarity between the samples at the 95 percent confidence level. From this, we can assert that overall the sample of responding innovators is not an overtly biased representation of the overall sample. In addition, we have confidence in extrapolating the citizenship status from our respondent sample onto our entire sample.

Figure 31: Predicted Distribution of Innovators Citizenship Status



By extrapolating our survey data to our sample, our guess is that the percentage of foreign-born innovators in the complete sample is 39 percent, compared with 35.5 percent among innovators responding. Second-generation Americans make up roughly 8 percent of our predicted distribution.

This gap is mostly caused by the significant difference in names guessed to be of Chinese origin in the complete sample and among respondents. The NamSor API guessed that 9.8 percent of the total sample population (and 9.7 percent of the sample for which we found emails) was of Chinese heritage. In comparison, only 6.6 percent of the population of responding innovators was guessed to be of Chinese heritage. Chinese names are 50 percent less common for innovators who responded as opposed to innovators who did not, indicating a significant response bias that underrepresents names guessed to be of Chinese origin.

Innovators from India are also slightly underrepresented, according to NamSor guesses. The NamSor API guessed that 9.1 percent of the total sample population was of Indic descent, compared with 7.4 percent of the sample for which we found emails and 8.1 percent of the population of responding innovators. Discounting the low rate of email discovery, the overall disparity between Indic names in the complete sample and among respondents is not significant.

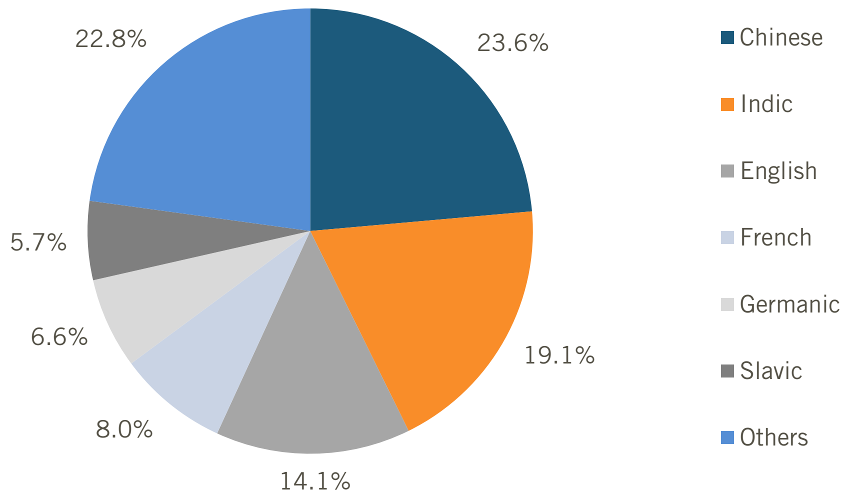


Figure 32: Predicted Distribution of Non-U.S. Citizens, by Language Family

Innovators from countries with Chinese-, Indic-, or English-language backgrounds make up more than half of foreign-born innovators in the United States. Most of the English language family foreign-born population is likely from the United Kingdom, as suggested by scientist survey data generated by the National Science Foundation.

APPENDIX F: SURVEY INSTRUMENT

Demographics

1. What is your name?
2. What is your gender?
    a. Female
    b. Male
3. In what year were you born?
4. What is the country of your birth?
5. What is the country of your mother's birth, if different from yours? (If the same, please skip)
6. What is the country of your father's birth, if different from yours? (If the same, please skip)
7. Do you consider yourself to be Hispanic or Latino?
    a. Yes
    b. No
8. What is your ethnicity? (Please select all that apply.)
    a. American Indian or Alaskan Native
    b. Asian or Pacific Islander
    c. Black or African American
    d. White/Caucasian
    e. Other
9. What was your religious upbringing? (Please select all that apply)
    a. Buddhism
    b. Catholicism
    c. Hinduism
    d. Inter/non-denominational
    e. Islam
    f. Judaism
    g. Protestantism
    h. Other Christian
    i. Other
    j. I did not have a religious upbringing

Education

10. What kind of undergraduate institution did you graduate from?
    a. U.S. 4-year public university or college
    b. U.S. 4-year private university or college
    c. Foreign university or college
    d. I do not have a 4-year undergraduate degree

11. What was the field of your primary undergraduate major?
    a. Business
    b. Engineering – Computer and electrical
    c. Engineering – Mechanical
    d. Engineering – Other
    e. Humanities
    f. Life sciences, medicine, or related field
    g. Math
    h. Physical sciences
    i. Social sciences
    j. Other
12. What advanced degrees have you received? Please select degree type and field (where applicable) for each.
    a. Degree Type
    b. Field of Study
13. Please list the degree granting institution for each advanced degree listed above.

Immigration and Institutional Affiliation

We will now ask questions based on the triadic patent you filed. Please answer the following questions as they pertain at the time of the innovation for which you filed the patent.

14. What was your immigration status at the time of the innovation?
    a. Born in the United States
    b. Naturalized U.S. citizen
    c. Green card holder
    d. On H-1B visa
    e. Student visa
    f. Other visa
    g. Not a resident of the United States at the time
15. Where did you live at the time when you developed the innovation?
    a. City
    b. State
16. What type of organization was your principal employer or affiliation at the time you developed the innovation?
    a. Publicly traded company
    b. Privately owned company
    c. Government organization or public research institution
    d. University
    e. Non-profit research institution

    f. Self-employed
    g. Other
17. What was your position at the university?
    a. Student
    b. Post-doc
    c. Research staff
    d. Untenured faculty
    e. Tenured faculty
    f. Other

Employer Details

18. Approximate number of employees at the company at the time of innovation?
    a. Fewer than 25
    b. Between 25 and 99
    c. Between 100 and 500
    d. More than 500
19. Approximate age of the company at the time of innovation?
    a. Less than 5 years
    b. Between 5 and 10 years
    c. Older than 10 years
20. Was this company a startup venture?
    a. Yes
    b. No
21. Did you receive any government funding support for the innovation? If so, please select all that apply.
    a. Small business innovation research (SBIR)
    b. Department of Defense
    c. Department of Energy
    d. National Institute of Health
    e. State government
    f. Other federal funding (please specify)
22. Was the innovation the product of collaboration with another institution?
    a. Yes
    b. No
23. What type of organization(s) did you collaborate with on the innovation?
    a. Publically traded company
    b. Privately owned company
    c. Government organization or public research institution
    d. University
    e. Non-profit research institution

f. Other

Commercialization

The final questions pertain to the current status of the innovation in the marketplace.

24. What is the current phase of commercialization of the innovation?
    a. Research phase
    b. Proof of concept
    c. Pilot
    d. Prototype
    e. Fully commercialized
25. What were the most significant barriers encountered in efforts to commercialize the innovation? (Select the top three barriers)
    a. Lack of funding for further development
    b. Insufficient market demand
    c. Technical in-feasibility of the innovation
    d. Regulatory challenges
    e. Competition from other innovators
    f. Other
    g. Not applicable
26. What has been the approximate cumulative revenue resulting from the innovation?
    a. Less than $25 million
    b. Between $25 million and $100 million
    c. Between $100 million and $500 million
    d. Greater than $500 million
    e. Do not know

Thank you

27. Is there anything else we should know about you or your innovation?

ENDNOTES

1. John P. Walsh and Sadao Nagaoka, "Who Invents?: Evidence from the Japan-U.S. Inventor Survey" (Research Institute of Economy, Trade and Industry, July 5, 2009), http://www.rieti.go.jp/jp/publications/dp/09e034.pdf.
2. Benjamin F. Jones, "Age and Great Invention" (working paper no. 11359, National Bureau of Economic Research (NBER), May 2005), http://www.nber.org/papers/w11359; Benjamin Jones, E.J. Reedy, Bruce A. Weinberg , "Age and Scientific Genius" (working paper no. 19866, National Bureau of Economic Research (NBER), January 2014), http://www.nber.org/papers/w19866.
3. Joseph A. DiMasi, "Briefing: Cost of Developing a New Drug" (briefing, Tufts Center for the Study of Drug Development, November 18, 2014), http://csdd.tufts.edu/files/uploads/Tufts_CSDD_briefing_on_RD_cost_study_-_Nov_18,_2014..pdf.
4. Benjamin F. Jones, "The Burden of Knowledge and the 'Death of the Renaissance Man': Is Innovation Getting Harder?" (working paper, National Bureau of Economic Research (NBER), May 2005), http://www.nber.org/papers/w11360.
5. Walsh and Nagaoka, "Who Invents?"
6. Edward B. Roberts and Charles Eesley, "Entrepreneurial Impact: The Role of MIT — An Updated Report," *Foundations and Trends in Entrepreneurship* 7, nos. 1–2 (2011): 1–149, https://ilp.mit.edu/media/webpublications/pub/literature/Entrepreneurial-Impact-2011.pdf.
7. "Women in STEM," The White House Office of Science and Technology Policy, accessed January 11, 2016, https://www.whitehouse.gov/administration/eop/ostp/women.
8. The proportion of females in STEM jobs is constant at 24 percent from 2000 to 2009; David Beede, et al., "Women in STEM: A Gender Gap to Innovation" (Washington, DC: U.S. Department of Commerce, Economics and Statistics Administration Issue Brief #04-11, August 2011), http://www.esa.doc.gov/sites/default/files/womeninstemagaptoinnovation8311.pdf.
9. Taehyun Jung and Olof Ejermo, "Demographic Patterns and Trends in Patenting: Gender, Age, and Education of Inventors," *Technological Forecasting and Social Change* 86 (July 2014), http://www.sciencedirect.com/science/article/pii/S0040162513001911.
10. Paola Giuriet al., "Everything You Always Wanted to Know About Inventors (But Never Asked): Evidence from the PatVal-EU Survey" (LEM working paper series, Laboratory of Economics and Management (LEM) at the Sant'Anna School of Advanced Studies, Pisa, Italy, February 2006, http://www.lem.sssup.it/WPLem/files/2005-20.pdf.
11. Ibid.
12. Pitchbook, Angel Seed and Early VC Deals (female founded/co-founded companies, 2000–2015; accessed November 11, 2015), http://pitchbook.com/venture-capital.
13. Jeffrey Mervis, "NIH Program Fails to Launch Blacks in Biotech," *Science* 350, no. 6263 (November 20, 2015): 896, www.sciencemag.org/content/350/6263/896.summary?rss=1.
14. "Darpa Robotics Challenge, Finals 2015," accessed December 2, 2015, http://www.theroboticschallenge.org/.
15. David M. Hart, Zoltan J. Acs, and Spencer L. Tracy, Jr., "High-Tech Immigrant Entrepreneurship in the United States" (Washington, DC: Small Business Administration (SBA), Office of Advocacy, July 2009), https://www.sba.gov/sites/default/files/rs349tot_0.pdf.
16. Ibid.
17. Hart, Acs, and Tracy, "High-Tech Immigrant Entrepreneurship," 35.
18. William R. Kerr, "U.S. High-Skilled Immigration, Innovation, and Entrepreneurship: Empirical Approaches and Evidence" (working paper, National Bureau of Economic Research (NBER), August 2013), http://www.nber.org/papers/w19377.
19. Vivek Wadhwa, *The Immigrant Exodus: Why America is Losing the Global Race to Capture Entrepreneurial Talent* (Philadelphia: Wharton Digital Press, 2012).
20. David M. Hart, "Founder Nativity, Founding Team Formation, and Firm Performance in the U.S. High-Tech Sector," *International Entrepreneur Management Journal*, May 21, 2011, http://davidhart.gmu.edu/pdfs/publications/articles_essays_reports/IEMJ%20published%20version%205-21-11.pdf.
21. Hart, "Founder Nativity."
22. Walsh and Nagaoka, "Who Invents?"
23. Ibid.

24. Due to a quota-based system for the main visa category (H1B) through which foreign-born professionals obtain eligibility to temporarily work in the United States, that serves as a sieve to allow individuals with necessary skills to enter the U.S. work force based on education. Foreign born individuals require some form of higher education certification to be eligible for this temporary work visa, with 20,000 slots added on for master's degree holders and higher in 2005. Wei Li and Lucia Lo, "Highly-Skilled Indian Migrations in Canada and the US: The Tale of Two Immigration Systems" (working paper no. 4, International Migration and Diaspora Studies Project (IMDS), 2009). However, green card applicants need only the equivalent of a high school diploma or work experience.
25. Jennifer Hunt, "Which Immigrants Are Most Innovative and Entrepreneurial? Distinctions by Entry Visa" (working paper no. 14920, National Bureau of Economic Research (NBER), April 2009), http://www.nber.org/papers/w14920.pdf.
26. Ibid.
27. Giovanni Peri, Kevin Y. Shih, and Chad Sparber, "Foreign STEM Workers and Native Wages and Employment in U.S. Cities" (working paper no. 20093, National Bureau of Economic Research (NBER), May 2014), http://www.nber.org/papers/w20093.
28. Yannu Zheng and Olof Ejermo, "Characteristics of Foreign-Born Inventors in Sweden" (paper presented at the DRUID Academy 2013, Skørping, Denmark, January 16–18, 2013), http://druid8.sit.aau.dk/druid/acc_papers/jlg2f36g3171tofl73ae4hteqblr.pdf.
29. Ibid.
30. Mervis, "NIH Program Fails."
31. Walsh and Nagaoka, "Who Invents?"
32. Jung and Ejermo, "Demographic Patterns and Trends."
33. Myriam Mariani and Marzia Romanelli, "'Stacking' or 'Picking' Patents? The Inventors' Choice between Quantity and Quality," (LEM working paper series, Laboratory of Economics and Management (LEM) at the Sant'Anna School of Advanced Studies, Pisa, Italy, February 2006), http://www.dime-eu.org/files/active/0/MarianiRomanelli.pdf.
34. Hunt, "Which Immigrants Innovative and Entrepreneurial?"
35. Hart, Acs, and Tracy "High-Tech Immigrant Entrepreneurship."
36. SESTAT Data Tool, Scientists and Engineers Statistical Data System; accessed December 17, 2015, http://ncsesdata.nsf.gov/sestat/sestat.html.
37. John P. Walsh, Hsin-I Huang, and Yeongji No, "The Knowledge Creation Process in American Science: Basic Findings from the American Scientists Survey" (final report to Hitotsubashi University, Tokyo, March 15, 2011), https://smartech.gatech.edu/bitstream/handle/1853/42333/114435_NISTEPFinalReport110315jw.pdf?sequence=1.
38. Richard Cuthbertson, Peder Inge Furseth, and Stephen J. Ezell, *Innovating in a Service-Driven Economy: Insights, Application, and Practice*, (London: Palgrave Macmillan UK, 2015), http://www.palgrave.com/us/book/9781137409010.
39. David M. Hart and Zoltan J. Acs, "Immigration and High-Impact, High-Tech Entrepreneurship," *Issues in Technology Innovation* 6 (February, 2011), http://www.brookings.edu/~/media/research/files/papers/2011/2/immigration-hart-acs/02_immigration_hart_acs.pdf.
40. R&D 100 Awards & Technology Conference website, accessed January 10, 2016, http://www.rd100awards.com/.
41. "2015 R&D 100 Award Winners," on R&D 100 Awards & Technology Conference website, accessed January 14, 2016, http://rd100awards.com/2015-rd-100-award-winners.
42. For OECD classification of triadic patents technology categories, see Appendix B.
43. Actual samples are slightly smaller than 100, given that some are pulled based on location outside of the United States.
44. "R&D 100 Awards History," on R&D 100 Awards & Technology Conference website, accessed December 5, 2015, http://www.rd100awards.com/rd-100-awards-history.
45. Fred Block and Matthew R. Keller, "Where Do Innovations Come From? Transformations in the U.S. National Innovation System, 1970–2006" (Information Technology and Innovation Foundation, July 2008), http://www.itif.org/files/Where_do_innovations_come_from.pdf.
46. Because triadic patents involve the same patent filed in the US, EU, and Japan patent offices, it represents a much higher cost, to undertake where innovators expect some form of global value to be extracted out

from their innovation, rather than only having impact domestically. The basic fees to file for a patent range from $160 in Japan, $230 in the EU, and $280 in the US, and legal fees can be incurred depending on the country and on the patent. "Fees," on Asia Patent Alliance website, accessed January 14, 2016, http://www.asiapatent.net/fees-g-104.html; "USPTO Fee Schedule," on United States Patent and Trademark Office website, accessed January 14, 2016, http://www.uspto.gov/learning-and-resources/fees-and-payment/uspto-fee-schedule; "Schedule of Fees and Expenses Applicable as from 1 April 2014," on European Patent Office website, accessed January 14, 2016, https://www.epo.org/law-practice/legal-texts/official-journal/2014/etc/se3/p1.html.

47. Innovators showing up multiple times in different samples were left in all samples in which they were randomly selected to reduce bias.
48. Expert opinion differs on what an acceptable response rate should be, leading to a range between 10 percent to 75 percent considered "acceptable." "How Many Is Enough? The Quest for an Acceptable Survey Response Rate," *Bright Ideas*, September 16, 2009, https://kkbiersdorff.wordpress.com/2009/09/16/how-many-is-enough/. An analysis of various academic articles that use a survey methodology reveal a reported response rate between 3 percent and 100 percent. Stephen A. Sivo et al., "How Low Should You Go? Low Response Rates and the Validity of Inference in IS Questionnaire Research," *Journal of the Association of Information Systems* 7, no. 6 (June 2006): 351–414, http://business.ucf.edu/wp-content/uploads/2014/11/How-Low-Should-You-Go..Low-Response-Rates-and-the-Validity-of-Inference-in-IS-Questionnaire-Research.pdf. More importantly, social science research places a greater emphasis on attempting to eliminate non-response bias, i.e., ensuring that those who did not respond to the survey tremendously bias a certain relevant demographic characteristic in the sample respondents. Timothy P. Johnson and Joseph S. Wislar, "Response Rates and Nonresponse Errors in Surveys," *The Journal of the American Medial Association* 307, no. 17 (May 2, 2012), http://jama.jamanetwork.com/article.aspx?articleid=1150104. Through novel onomastic data mining techniques detailed in Appendix E, we are statistically confident that our respondents are not biased by either sex or ethnicity.
49. Response rates exclude responses rejected based on either insufficiently incomplete response data or respondents stating they were outside the United States at the time of the innovation. It should be noted that the response rate among the large tech companies sample is influenced by the fact that 100 percent of innovators in the sample are represented, as opposed to other samples where only innovators successfully contacted are considered. Anonymous responses are also excluded from these samples, as we cannot tell whether these innovators belong to the portion of the sample that was eliminated due to insufficient response rates. A grand total of 964 survey responses were collected across the five samples. Of these, we removed 10 respondents with insufficient data or clearly erroneous data (the software counted a survey as complete even if the innovator answered only one question). Thirty-two innovators were removed from the sample if their answer to the question "Where were you located at the time of the innovation?" was outside the United States, as our methodology looks specifically to find demographic information surrounding innovators currently based in the United States. After these reductions, 923 responses remained, or 9.4 percent of the original sample of 9,756 innovators. A summation of all innovators in the five samples is 9,755. It includes several innovators operating outside the United States, whose responses were removed, but also included anonymous responses from the large tech companies' patent sample who may have been employed by those institutions cut because of very low response rates.
50. Anonymous responses were not significantly different in composition in terms of gender or country of origin. However, anonymous responses were significantly younger than the rest of responses.
51. See endnote 48.
52. This finding was significant at a 5 percent confidence level.
53. NamSor homepage, accessed July 25, 2015, http://www.namsor.com/.
54. Through a chi-square test, we compared the distribution of the respondents by their country's root language family against the entire sample of predicted countries, and the predicted countries of all innovators whom we were able to obtain an email of (i.e., the innovators sent the survey). A p-value of 0.12 indicates statistical confidence at the 95 percent level that the country of origin distributions between these three samples were more similar than different. This allows us to make the statistical claim that our respondent pool is representative of our entire sample of innovators, and that findings from the respondent pool can be extrapolated onto the larger sample.
55. A chi-square test analyzed the distribution of Chinese heritage innovators who responded against Chinese heritage innovators in our whole sample, and those for whom we had found an email. No sizable

difference existed between the proportion of Chinese heritage innovators in the entire sample and the sample of innovators with emails. With a p-value of 0.01 from the chi-square test, we are statistically confident at the 95 percent level that the proportion of innovators with Chinese heritage in our respondent pool is different from the proportion of Chinese heritage innovators from the entire sample. Such findings suggest that it was not a data collection issue that lead to the low eventual response rates for Chinese heritage innovators.

56. A chi-square test analyzed the distribution of Indic heritage innovators who responded against Indic heritage innovators in our whole sample, and those for whom we had found an email. Though not a sizable difference exists between the proportion of Indic heritage innovators in the response pool compared to the overall sample, methodologically, we were unable to gather a similar proportion of Indic heritage innovator emails. A p-value of 0.00 provides statistical evidence that we are 95 percent confident that the samples are different to one another. In particular, this observation does not make much of a difference to our results because the shortcomings of our email data collection were compensated by an overrepresentation of Indic heritage innovators responses. If both our email collection sample and overall sample were not statistically different for Indic heritage innovators, we would likely have encountered a situation reverse that of Chinese heritage innovators, an over presentation of Indic innovators in our final findings.
57. The estimated percentage of fe males for non-anonymous respondents (n=744) was 12.1 percent, compared to an estimated mean of 13.4 percent for the remainder of the overall sample (n=9005). Running a chi-square test yielded a p-value of 0.19, allowing the rejection of the null hypothesis at the 5-percent level. This means that there is little differen ce between the gender distributions of the innovators who responded compared to the gender distribution of the entire sample.
58. For percentage of females by country or region of birth, the difference in female proportion from the U.S. sample was statistically significant for China, 'elsewhere,' and 'total foreign-born' at the 5-percent level. The difference in percentage of females in Europe and the United States was significant at the 10-percent level.
59. Institute of Education Sciences, National Center for Educational Statistics (digest of educational statistics: 2013, table 318.10. degrees conferred by degree-granting postsecondary institutions, by level of degree and sex of student: selected years, 1869–70 through 2023–24; accessed December 10, 2015), http://nces.ed.gov/programs/digest/d13/tables/dt13_318.10.asp?referrer=report.
60. National Science Foundation, Statistics (science and engineering degrees, by race/ethnicity of recipients: 2002–2012; accessed December 10, 2015), http://www.nsf.gov/statistics/2015/nsf15321/#chp2.
61. American Physics Society, Fraction of Bachelor's Degrees in STEM Disciplines Earned by Women (Women's Bachelor's – STEM data, 1966–2015; accessed November 5, 2015); http://www.aps.org/programs/education/statistics/womenstem.cfm.
62. Ibid; Institute of Education Sciences (table 318.10); United States Census Bureau (state & country quickfacts, United States; accessed January 10, 2016, http://quickfacts.census.gov/qfd/states/00000.html; Institute of Education Sciences, National Center for Educational Statistics, (digest of educational statistics, doctor's degrees conferred by postsecondary institutions, by race/ethnicity and sex of student: selected years, 1976–77 through 2011–12; accessed December 15, 2015), http://nces.ed.gov/programs/digest/d13/tables/dt13_324.20.asp.
63. Innovators responding as White/Caucasian and Hispanic were coded as Hispanic.
64. United States Census Bureau, (state & country quick facts, United States, people quickfacts; updated December 2, 2015), http://quickfacts.census.gov/qfd/states/00000.html.
65. Min Zhou and Jennifer Lee, "Assessing what is cultural about Asian Americans' academic advantage," *PNAS,* 2014 111: 8321-8322. http://www.pnas.org/content/111/23/8321.full.pdf.
66. Institute of Education Sciences (doctor's degrees postsecondary institutions).
67. National Science Foundation, Survey of Doctorate Recipients (table 3. doctoral scientists and engineers, by broad field of doctorate, employment status, ethnicity, and race: 2013; accessed December 2, 2015), http://ncsesdata.nsf.gov/doctoratework/2013/html/SDR2013_DST3.html.
68. U.S. Census Bureau (state & country quickfacts); Institute of Education Sciences (doctor's degrees postsecondary institutions).
69. Ibid.
70. United States Census Bureau, (population projections, table 13. projections of the population by nativity, Hispanic origin, and race for the United States: 2015 to 2060; accessed January 10, 2016, http://www.census.gov/population/projections/data/national/2014/summarytables.html; Institute of

Education Sciences (doctor's degrees postsecondary institutions); National Science Foundation, Survey of Doctorate Recipients (table 3); National Science Foundation, National Center for Science and Engineering Statistics (scientists and engineers statistical data system (SESTAT), 2003 and 2013; accessed December 1, 2015), http://www.nsf.gov/statistics/sestat/#sestat-data&datatables.

71. Jie Zong and Jeanne Batalova, "Frequently Requested Statistics on Immigrants and Immigration in the United States" (Migration Policy Institute, February 26, 2015); http://www.migrationpolicy.org/article/frequently-requested-statistics-immigrants-and-immigration-united-states.
72. Adams B. Nager and Robert D. Atkinson, "Debunking the Top Ten Arguments Against High-Skilled Immigration" (Information Technology and Innovation Foundation, April 2015), http://www2.itif.org/2015-debunking-myths-high-skilled.pdf.
73. Excludes five responses stating "other," which are coded as foreign-born but not assigned a region.
74. Nancy Rytina, "Estimates of the Legal Permanent Resident Population in 2011" (Washington, DC, U.S. Department of Homeland Security Office of Immigration Statistics, July 2012); https://www.dhs.gov/xlibrary/assets/statistics/publications/ois_lpr_pe_2011.pdf.
75. National Science Foundation (SESTAT).
76. Ibid.
77. The vast majority of innovators with foreign bachelor's degrees are immigrants. Only three U.S.-born innovators reported going to school abroad.
78. Institute of Ediucation Sciences, National Center for Educational Statistics, (2014 digest of educational statistics, table 105.20. enrollment in elementary, secondary, and degree-granting postsecondary institutions, by level and control of institution, enrollment level, and attendance status and sex of student: selected years, fall 1990 through fall 2024, 2012; accessed January 15, 2016), http://nces.ed.gov/programs/digest/d14/tables/dt14_105.20.asp?current=yes.
79. Center for STEM Education & Innovation, "Where Are Students Getting Science Bachelor's Degrees? What Are They Paying?" (American Institutes for Research, September, 2013), http://www.air.org/sites/default/files/STEM%20Science%20Bachelors_Where%20and%20how%20much.pdf.
80. "All Other Majors" includes innovators who responded to the undergraduate major question with "Social Sciences," "Humanities," "Business," or "Other."
81. Institute of Education Sciences, National Center for Educational Statistics, (degrees conferred by public and private institutions, table 1, 2012–2013, updated April 2015; accessed December 22, 2015), http://nces.ed.gov/programs/coe/indicator_cvc.asp.
82. Degree institution had a low number of responses, with only 49.9 percent of innovators listing at least one advanced degree corresponding with the name of their university.
83. The difference is significant at 1 percent.
84. National Science Foundation, Survey of Doctorate Recipients (employed doctoral scientists and engineers; source: survey of doctorate recipients 2003, 2006, 2008, 2010, 2013; accessed December 15, 2015), http://www.nsf.gov/statistics/srvydoctoratework/#tabs-2&tools.
85. Ibid.
86. Mean of 47.4 years of age at the time of innovation.
87. Rebecca Riffkin, "Americans Settling on Older Retirement Age," *Gallup*, April 29, 2015, http://www.gallup.com/poll/182939/americans-settling-older-retirement-age.aspx
88. Statistically significant at the 1 percent confidence level.
89. Bureau of Labor Statistics, Employment Projections (median age of the labor force, by gender, race and ethnicity, 1994, 2004, 2014 and projected 2024; accessed December 8, 2015); http://www.bls.gov/emp/ep_table_306.htm.
90. Averages for age groups by gender and country of origin are as follows: U.S.-born males 48.2 years, U.S.-born females 45.3 years, foreign-born males 46.9 years, and foreign-born females 43.1 years.
91. Standard deviation in age for foreign-born innovators is 9.4 years, compared to 10.4 years for U.S.-born innovators.
92. The T-test for a two-tailed value for age of foreign-born innovators and U.S.-born innovators has a P-value of 0.047. The P-value of the difference in age of male and female innovators is 0.0036. Both are considered significant at the 5 percent confidence level.
93. The process excludes those who elected to remain anonymous and therefore cannot be matched to a specific innovation.

94. Where an innovation is the result of collaboration, fractions based on the number of respondents identifying with each collaboration institution as a percentage of all respondents were used, so results sum to 100 percent. For instance, an innovation with four respondents, three of whom worked for a university and one of whom worked for a publically traded company, would be scored as 0.75 for university and 0.25 for publicly traded company.
95. For purposes of measuring location, we exclude the large tech companies sample, whose location is largely determined by the companies included and thus does not represent an independent look at where innovation takes place.
96. Robert D. Atkinson and Adams B. Nager, "The 2014 State New Economy Index" (Information Technology and Innovation Foundation, June 2014), https://itif.org/publications/2014/06/11/2014-state-new-economy-index.
97. Ibid.
98. Ibid.
99. Some patents had more than one response logged as a result of innovations completed as collaboration between two organizations or conflicting responses; rows sum up to 100.
100. While we have no means of confirming this trend or guessing at its impact, there is historical evidence to show that often, large firms acquire small firms who have successfully innovated. If respondents in these cases report being employed by a large firm at the time of innovation, despite having largely conducted the research as a small firm, small firms may be underrepresented in the sample.
101. United States Census Bureau, Statistics of U.S. Businesses (U.S. & states, NAICS sectors and employment size, 2012; accessed December 14, 2015), http://www.census.gov/econ/susb/.
102. Ibid.
103. This distinction is statistically significant at the 5 percent confidence level with a p-value of 0.039. The relationship between foreign-born and U.S.-born innovators is significant at the 10 percent level, with a p-value of 0.077.
104. Some patents had more than one response logged as a result of innovations completed as collaboration between two organizations or conflicting responses. Rows sum up to 100 percent. Large tech companies were excluded from totals.
105. United States Census Bureau, Business Dynamics Statistics (firm characteristics data tables, firm age by firm size, employment tab; accessed January 4, 2016), http://www.census.gov/ces/dataproducts/bds/data_firm.html.
106. Ewing Marion Kauffman Foundation, "Entrepreneurship Policy Digest" (policy brief, Kauffman Foundation, September 14, 2015), http://www.kauffman.org/~/media/kauffman_org/resources/2014/entrepreneurship%20policy%20digest/september%202014/entrepreneurship_policy_digest_september2014.pdf.
107. Matt Stepp and Robert D. Atkinson, "Creating a Collaborative R&D Tax Credit" (Information Technology and Innovation Foundation, June 2011), http://www.itif.org/files/2011-creating-r&d-credit.pdf.
108. Peter L. Singer, "Federally Supported Innovations: 22 Examples of Major Technology Advances That Stem From Federal Research Support" (Information Technology and Innovation Foundation, February 2014), http://dc.mit.edu/sites/default/files/2014-federally-supported-innovations-1.pdf.
109. "About SBIR," Small Business Innovation Research (SBIR), accessed January 29, 2016, https://www.sbir.gov/about/about-sbir.
110. A total of 29.6 percent of innovations created by private firms with fewer than 100 employees received SBIR grants.
111. Some patents had more than one response logged as a result of innovations completed as collaboration between two organizations or conflicting responses. Rows sum up to 100 percent.
112. R&D 100 Awards are expected be severely biased here, as a requirement for Award consideration is a working, marketable product.
113. The main difficulty in gaining accurate insights fr om commercialization rates stems from the time lag between identifying the sample and the responses garnered from the survey. Innovations patented in 2011 had more time to reach the marketplace and generate income than innovations patented in 2014. We did see statistically significance differences at the 5 percent confidence level between commercialization rates for innovation from 2011 and 2014 across R&D 100 Awards and life sciences, materials sciences, and information technology patents.

114. Because this question was only posed to innovators with commercialized innovations, the response rate is lower than in the rest of the survey.
115. Cumulative revenue of innovation was only recorded for fully commercialized innovations. Rows sum up to 100 percent. Only 227 innovations were reported as fully commercialized. We collected responses for 200 innovations that revealed the revenue collected from their respective projects. Unfortunately, of the 200 responses, we only know the value 130 of these innovations —roughly 60 percent of fully commercialized innovations. A significant difference in responses comes from inventions from large tech companies where only 40 percent of patent holders were aware of the revenue their inventions generated (likely because the innovation was an improvement on an existing product or process and not a stand-alone product or technology). This trend falls in line with the expectation that patents in large tech companies may be part of a larger chain and embodied in other products, thus obscuring the revenue produced from one specific invention. Besides that, it is likely that due to the departmental nature of large companies, inventors may be less aware of the eventual financial success of their products. Of our three major patent categories, inventors from the information technology field are more likely to know the commercial success of their inventions and those from the life sciences field are least likely to know.
116. The relationship is statistically significant at the 5 percent level.
117. Stephen Ezell and Robert D. Atkinson, "25 Recommendations for the 2013 America COMPETES Act Reauthorization" (Information Technology and Innovation Foundation, April 2013), https://itif.org/publications/2013/04/22/25-recommendations-2013-america-competes-act-reauthorization; "Tech Policy 2016: What Presidential Candidates Should Be Talking About (Information Technology and Innovation Foundation, June 2015), https://itif.org/publications/2015/06/17/tech-policy-2016-what-presidential-candidates-should-be-talking-about; Robert D. Atkinson and Merrilea Mayo, "Refueling the U.S. Innovation Economy: Fresh Approaches to Science, Technology, Engineering and Mathematics (STEM) Education" (Information Technology and Innovation Foundation, 2010), http://www.itif.org/files/2010-refueling-innovation-economy.pdf.
118. Giuri et al., "Inventors and Invention Processes in Europe: Results from the PatVal-EU Survey," *Research Policy* 36, no. 8 (October 2007): 1107–1127, http://www.sciencedirect.com/science/article/pii/S0048733307001473.
119. Organisation for Economic Co-operation and Development (OECD), Patents by Technology (triadic patent families, inventor(s)'s country(ies) of residence, 2000–2012; accessed October 14, 2015), http://stats.oecd.org/Index.aspx?DatasetCode=PATS_IPC.
120. "U.S. Patent Statistics Chart, Calendar Years 1963–2014," U.S. Patent and Trademark Office, Patent Technology Monitoring Team (PTMT), accessed January 6, 2015, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/us_stat.htm.
121. Organisation for Economic Co-operation and Development (OECD), OECD Patent Database, accessed January 10, 2015, http://www.oecd.org/sti/inno/oecdpatentdatabases.htm.
122. Ibid.
123. Jean Lanjouw and Mark Schankerman, "The Quality of Ideas: Measuring Innovation with Multiple Indicators" (working paper no. 7345, National Bureau of Economic Research (NBER), September, 1999), http://www.nber.org/papers/w7345.pdf.
124. Helene Dernis, and Mosahid Kahn, "Triadic Patent Families Methodology" (working paper 2004/2, OECD Science, Technology and Industry), http://www.oecd-ilibrary.org/docserver/download/5lgsjhvj7kkb.pdf?expires=1454984665&id=id&accname=guest&checksum=ABAEBAC42DE56DACBA41341549422FCC.
125. Ikuo Kuroiwa, Kaoru Nabeshima, Kiyoyasu Tanaka, "Innovation Networks in China, Japan, and Korea: Evidence from the Japanese Patent Data," (discussion paper no. 285, Institute of Developing Economies, March, 2011), http://www.ide.go.jp/English/Publish/Download/Dp/pdf/285.pdf; Pieter Stek and Marina van Geenhuizen, "Measuring the Dynamics of an Innovation System Using Patent Data: A Case Study of South Korea, 2001–2010," *Quality & Quality* 49, no. 4 (July 2015): 1325–43, http://link.springer.com/article/10.1007%2Fs11135-014-0045-4; Roger Svensson, "Measuring Innovation Using Patent Data" (working paper no. 1067, Research Institute of Industrial Economics, 2015), http://www.ifn.se/wfiles/wp/wp1067.pdf.

126. David Popp, “Using the Triadic Patent Family Database to Study Environmental Innovation” (Paris: Organisation for Economic Co-operation and Development, 2005), http://www.oecd.org/env/consumption-innovation/38283097.pdf.
127. Walsh and Nagaoka, “Who Invents?”
128. “The Georgia Tech/RIETI Innovator Survey,” Georgia Tech School of Public Policy, http://www.prism.gatech.edu/~jwalsh6/inventors/invent.html.
129. The original methodology attempted to create a sample with seven large tech companies. As with all data relating to individual innovators and firms, the firms that make up the large tech companies sample are left anonymous.
130. A count of emails marked as undeliverable indicates only around 50 to 60 percent of emails made it to their destination.
131. Lawrence Livermore National Laboratory, website, http://www.llnl.gov.
132. Validation websites include http://www.verifyemailaddress.org/, http://verify-email.org/, and http://validateemailaddress.org/.
133. Namsor homepage, accessed November 7, 2015, http://www.namsor.com/.

ACKNOWLEDGMENTS

ITIF appreciates the financial support received from the Smith Richardson Foundation for this project. The content and views of this publication are solely the responsibility of ITIF.

The authors would like to thank Alfred Sarkissian and Ben Shearn for tireless effort to collect contact information for all the innovators included in this survey. Furthermore, they thank John Wu for his help analyzing response data for this report.

The authors wish to thank Delton Daigle and Alex Key for providing input to this report. Any errors or omissions are the authors' alone.

ABOUT THE AUTHORS

Adams B. Nager is an economic policy analyst at ITIF. He researches and writes on innovation economics, manufacturing policy, and the importance of STEM education and high-skilled immigration. Nager holds an M.A. in political economy and public policy, and a B.A. in economics, both from Washington University in St. Louis.

David M. Hart is professor and director of the Center for Science and Technology Policy at the School of Policy, Government, and International Affairs at George Mason University and a member of the board of ITIF. His books include *Unlocking Energy Innovation* (MIT Press, 2012, co-authored with Richard K. Lester).

Stephen J. Ezell is vice president, global innovation policy at ITIF, where he focuses on innovation policy as well as international competitiveness and trade policy issues. He is the co-author of *Innovation Economics: The Race for Global Advantage* (Yale, 2012) and *Innovating in a Service-Driven Economy: Insights, Application, and Practice* (Palgrave McMillan, 2015).

Robert D. Atkinson is the founder and president of ITIF. He is also the co-author of the book *Innovation Economics: The Race for Global Advantage* (Yale, 2012). Atkinson received his Ph.D. in City and Regional Planning from the University of North Carolina at Chapel Hill in 1989.

ABOUT ITIF

The Information Technology and Innovation Foundation (ITIF) is a nonprofit, nonpartisan research and educational institute focusing on the intersection of technological innovation and public policy. Recognized as one of the world's leading science and technology think tanks, ITIF's mission is to formulate and promote policy solutions that accelerate innovation and boost productivity to spur growth, opportunity, and progress.

FOR MORE INFORMATION, VISIT US AT WWW.ITIF.ORG.