Patenting Prosperity:

Invention and Economic Performance in the United States and its Metropolitan Areas

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“Inventive capacity and activity—including R&D investment, a science-oriented workforce, collaboration, and patented output—are realized most completely in the nation’s metropolitan areas.”

An analysis of national and metropolitan area invention from 1980 to 2012, using a new comprehensive database of patents, reveals:

- **The rate of patenting in the United States has been increasing in recent decades and stands at historically high levels.** Growth in patent applications slowed after the IT bubble and the Great Recession, but the rate of patenting by U.S. inventors is at its highest point since the Industrial Revolution. Moreover, patents are of objectively higher value now than in the recent past and more evenly dispersed among owners than in previous decades. Still, the United States ranks just ninth in patents per capita using appropriate international metrics, as global competition has increased.

- **Most U.S. patents—63 percent—are developed by people living in just 20 metro areas, which are home to 34 percent of the U.S. population.** Reflecting the advantages of large metropolitan economies, 92 percent of U.S. patents are concentrated in just 100 metro areas, with 59 percent of the population. For patents applied for from 2007 to 2011, the metro areas with the highest number per capita are San Jose; Burlington, VT; Rochester, MN; Corvallis, OR; and Boulder, CO.

- **Inventions, embodied in patents, are a major driver of long-term regional economic performance, especially if the patents are of higher quality.** In recent decades, patenting is associated with higher productivity growth, lower unemployment rates, and the creation of more publicly-traded companies. The effect of patents on growth is roughly equal to that of having a highly educated workforce. A low-patenting metro area could gain $4,300 more per worker over a decade’s time, if it became a high-patenting metro area.

- **Research universities, a scientifically-educated workforce, and collaboration play an important role in driving metropolitan innovation.** Metro areas with high patenting rates are significantly more likely to have graduate programs in science, especially high-ranking programs, even adjusting for tech sector employment. A high share of college graduates from science fields is also strongly related to higher patenting levels and rates. Additionally, metro areas that collaborate more on patenting, patent more.

- **Patents funded by the U.S. government tend to be of especially high quality, and federal small business R&D funding is associated with significantly higher metropolitan productivity growth.** The U.S. government supports more basic research than the private sector, and so outputs are more likely to be scientific publications than patents. Still, the patents and other research projects that are supported appear to be highly valuable to both regions and society.

For all the success of the United States, the value of invention is not evenly shared across regions because of the clustering of assets like science majors, tech sector workers, and leading research universities. As a result, metropolitan, state, and federal policy makers need to consider ways to foster these attributes more broadly and generally support research and development, as discussed below. The report also recommends reforms to patent law to protect startups and other productive companies from frivolous and expensive legal challenges.

Introduction

Innovation is central to economic growth.[1] Arguably, the most valuable innovations have been embodied in technologies that perform work, such as the provision of energy or health, product assembly, information storage and retrieval, and transportation, to name just a few functions. Such technologies have radically transformed the way humans live for the better and, along with political reforms, have allowed hundreds of millions of men and women descended from serfs, slaves, and peasants to obtain a measure of health and affluence previously available only to elites.[2]

In the midst of a weak recovery from a particularly severe recession, many people are wondering whether the United States is in a state of decline, lacking the dynamism it once had.[3] According to one recent survey, more Americans think the nation's best days are in the past, not the future.[4] Among the long-run drivers of innovation, economists have been identified factors such as education and political institutions that enforce basic rights and treat people as equals.[5] There are reasons to be concerned: The growth rate of adults obtaining a college education has slowed over the last three decades, test scores are low compared to other developed countries, income inequality has increased, and U.S. political institutions have become ideologically polarized.[6] Moreover, some argue that U.S. inventive output is flagging in the face of other related challenges, including global competition, increasing technological complexity, and weak public sector support relative to other countries.[7]

More fundamentally, the United States still ranks very high globally on a number of important measures of innovative capacity, though other developed countries have caught up or overtaken it. One study rates the United States fourth in the world in terms of innovative capacity but notes that it ranks near the bottom on changes over the previous ten years in the underlying variables.[8] On the weaker side, using internationally-oriented patent applications filed from 2000 to 2010 per resident, the United States ranks somewhat lower at ninth, and it is just 13th on science and engineering publications per capita.[9] More positively, the United States ranks third on GDP per worker, behind only Luxembourg and oil-rich Norway.[10] On R&D spending per capita, it ranks second, behind only Finland.[11] Finally, according to the Leiden Ranking (from Leiden University in the Netherlands), all ten of the world's top research universities are in the United States and 43 of the top 50, led by MIT, Princeton, Harvard, and Stanford.[12] All of these factors play a role in American innovation.

The focus of this report is on inventive activity, which yields enormous benefits to society that go well beyond the gains from inventors and producers.[13] One measure of inventive activity—the number of patents granted per person—has been increasing in the United States, alongside research and development.[14] Some scholars have even suggested that too many patents have been granted and attribute an increase to the declining rigor of approval standards.[15] Yet, there is a large body of compelling evidence showing that most patents do actually represent valuable inventions, especially "high quality" patents—meaning those that are highly cited or those that advance more intellectual property claims.[16] Despite wide variation in value, economists have calculated that the average patent is worth over half a million dollars in direct market value (and considerably more in social value as the technology and its ideas become diffused).[17] These estimates are consistent with recent patent sales reported in the media from Eastman Kodak, Motorola, Nortel, and Nokia, which have ranged $477,000 to $760,000 per patent, and even single patents from relatively unknown companies list patent prices at an online website for $1 million.[18] Still, some are sold for much less, and others never generate any market or social value or become obsolete after a few years. For example, despite the large legal costs of obtaining a patent, 16 percent of patents are allowed to expire after just four years because the owners refuse to pay even a $900 maintenance fee.[19] In any case, there is evidence that patent value is increasing. One indication is that scientific and technical research is increasingly collaborative in the United States and globally, and this appears to be leading to more valuable patents and publications.[20] Another is that corporate income from manufacturing sector royalties—which come largely from the licensing of patents—increased by 89 percent from 1994 to 2009, almost double the growth rate of patents granted to domestic inventors.[21]

However measured, inventive capacity and activity—including R&D investment, a science-oriented workforce, collaboration, and patented output—are realized most completely in the nation's metropolitan areas. Their overlapping social and infrastructure networks, linking and fostering interactions among individuals and businesses have made cities and their surrounds, since their very beginnings, the privileged settings for invention and innovation. As Adam Smith argued in the 18th Century, the large population size of metropolitan regions fosters trade and specialization, which increases productivity and frees people up for research activity.[22] Moreover, metropolitan areas facilitate the matching of workers to firms, learning between specialists, and the sharing of suppliers, customers, and regional assets.[23] Consequently, patenting activity in the United States has always been largely an urban phenomenon and is highly concentrated in large metro areas today.[24] This is also true globally: 93 percent of the world's recent patent applications were filed by inventors living in metropolitan areas with just 23 percent of the world's population.[25]

While U.S. invention remains a global force, a survey of the innovation related literature reveals that the country needs to work out a few crucial problems if it is to realize its potential for economic and social progress. First, while R&D spending continues to increase at roughly the same rate as GDP, there is evidence that inventions are becoming more expensive, more difficult, and more internationally competitive such that an even deeper commitment will be needed in both the near term and thereafter. Moreover, as the nation addresses its public finance problems, there will be pressure to cut R&D support. In fact, the federal commitment has already been shrinking in that spending has not kept up with GDP. This trend should be reversed. The public sector has a vital role to play in supporting innovation and invention.

Second, the nation's unequal access to high quality schooling means that too few—especially those born into lower income families—are academically prepared to meaningfully contribute to invention, and that not only delimits economic opportunity, it deprives the innovation system of a large number of people who might otherwise make or commercialize important discoveries.[26] This was not the case during America's most productive decades of the industrial revolution—after the Civil War and into the early 20th Century—when patenting was "democratized" and mostly done by blue collar workers, many of whom were not professional inventors.[27]

Third, while the patent system is not fundamentally broken, neither is it functioning as efficaciously as possible. Some have concluded that the entire system should be abolished based on such considerations.[28] That would be a big mistake. Recognizing that ideas can be easily transmitted, copied, and reproduced, the nation's founders, including Madison and Jefferson, took for granted that the patent system was an obvious and necessary means to promote invention.[29] All but a tiny fraction of the early industrial revolution's great inventions were patented.[30] Of 5,000 start-up companies founded in 2004, the share receiving venture capital financing—an indicator of market viability—was 14 times higher for companies with patents.[31] Comparative economic studies of patent systems tend to verify the Madisonian view, and industries that rely more on patenting are more competitive than those that do not.[32] The increase in formal litigation is a problem, but it has roughly grown at the same pace as the increase in patents.[33]

Still, in patent law's delicate balancing of incentives to invent with competition, the academic community has largely concluded that the balance leans too heavily in favor of intellectual property protection, especially with respect to the U.S. Patent and Trademark Office (USPTO), which is regarded by some scholars as less rigorous than the European Patent Office (EPO) or even the Japanese Patent Office (JPO).[34] Concerns include, but are not limited to, a decline in the quality of patents being issued, the granting of excessively broad claims over questionable subject matter, the granting of patent protection to "nature," to functions, or otherwise inappropriate subject matter, the difficulty of entering markets with many patents, and abuse of the legal system to extract rewards for infringement without contributing to innovation. The growing popularity of open-source software is something of a rebuke to the patent system.[35]

It should be noted that Congress and the USPTO are aware of these concerns, and the pendulum may be swinging in the other direction.[36] The American Invents Act, signed into law in 2011, was designed, in part, to address them by taking steps to increase examination quality and make abusive litigation less likely. Likewise, a 2012 Supreme Court decision clarified limitations on patenting laws of nature.[37] A similar clarification of rules with respect to software patents would be valuable in clarifying that functions, as opposed to the means of performing functions through software code or processes, should not be granted patents.[38] Moreover, there is disturbing evidence that non-producing entities (NPEs or firms deemed "trolls") are taxing productivity activity by buying up large patent portfolios with the sole purpose of suing producers. Such is the problem that the Department of

Justice and the Federal Trade Commission hosted a recent workshop on the anti-competitive implications of these trends.[39] More specifically, survey-based evidence reveals that trolls are extracting billions of dollars (as much as $29 billion in 2011) in payment, and that they often target small players, often startups, imposing huge cost burdens, while suppressing production.[40] In 2011, they initiated an estimated 40 percent of lawsuits, up from 22 percent in 2007.[41] Other studies have shown that NPEs account for most cases involving frequently litigated patents, and that NPEs tend to acquire very high-value patents for that purpose.[42] Settlements reached out of court often do not result in any public records, but there is now abundant anecdotal evidence and a growing sense of outrage that non-producers are effectively extorting companies on a large scale.[43] This needs to be resolved.

Finally, the nation must wrestle with the geography of innovation. As economist Enrico Moretti has persuasively argued, highly educated metropolitan areas have grown increasingly apart on measures of income and even health than less educated metropolitan areas in recent decades, reflecting the importance of industry clusters and urban economics in a technologically-infused world that increasingly rewards education.[44] Less educated areas where temporarily bolstered by the housing bubble because of their cheap land value and labor costs, and even highly educated areas were often seduced into supporting large and wasteful public investments in consumer projects—like new sports complexes.[45] A better use of local, state, and—when appropriate—federal dollars would be on shoring up a region's market failures or otherwise helping to solve pressing needs for things like educated workers, investment capital, infrastructure, or research institutions. For example, a remarkable study from Finland found that the opening of three technical research universities boosted patenting there by 20 percent, with large effects on engineering education near the universities.[46]

With these concerns in mind, this report examines the importance of patents as a measure of invention to economic growth and explores why some areas are more inventive than others. Why should we expect there to be a relationship between patenting and urban economic development? As economist Paul Romer has written, the defining nature of ideas, in contrast to other economic goods, is that they are non-rival: their use by any one individual does not preclude others from using them.[47] Although useful ideas can be freely transmitted and copied, the patent system guarantees, in principle, temporary protection from would-be competitors in the marketplace (i.e. excludability). Thus, one would expect regions to realize at least some of the value of invention, as has been shown for individual inventors and companies that patent.[48] Yet there is no guarantee that patents generated in a specific location will generate wealth in that same location—a set of conditions (the presence of a skilled and diverse labor force, an "ecosystem" of businesses providing complementary goods and services, financing and marketing capabilities among them) have to be met for invention to be commercialized. Research has established that patents are correlated with economic growth across and within the same country over time.[49] Yet, metropolitan areas play a uniquely important role in patenting, and the study of metropolitan areas within a single large country—the United States—allows one to isolate the role of patents from other potentially confounding factors like population size, industry concentration, and workforce characteristics.

After briefly summarizing the methods used to address these issues, the report proceeds with an analysis of U.S. trends in patenting, with a view to addressing the vibrancy, or lack thereof, in U.S. economic performance. It also assesses how the quality of patents has changed over time and depends on the source of funding. Then the analysis turns to the role of metro areas in invention and the effects that invention has on regional economic development, measured by productivity and unemployment. This study also goes deeper to explore the role of universities and other local institutions as well as science-educated workforce in accounting for why some areas patent more than others. The report concludes with reform proposals to protect innovative companies from unwarranted legal costs and boost innovation. It also explains why public investments in R&D and deployment are needed to realize the country's full potential to innovate, and how educational inequality is hindering U.S. economic performance.

Methods

Source and Description of Patent Data

The USPTO maintains patent records from its founding in 1790. Yet, for research purposes, much of the information from previous centuries has not been digitized and thus is not readily available for research use. Starting with patents granted in1975, however, the USPTO has digitized information on inventor and assignee (patent owner) names, as well as addresses and other detailed characteristics of the patent.

More detailed methodology can be found on the report's web page at www.brookings.edu/research/reports/2013/02/patenting-prosperity-rothwell or directly at www.brookings.edu/sitecore/shell/~/media/Research/Files/Reports/2013/02/patenting prosperity rothwell/patenting-prosperity-rothwell-appendix.pdf.

Deborah Strumsky has assembled this information and organized it into what is the most up-to-date and complete research database of all patenting activity that the authors are aware of, which is why we call it the **Strumsky Patent Database**. It is similar in many respects to the COMETS database and the NBER patents database, which are both excellent resources for patent scholars.[50] Still, the Strumsky Database has some unique features listed here:

- Complete coverage of all patents—including plant and design patents—from 1975 to 2012 (March 20, 2012 for this analysis).
- Using a distinct algorithm, it links inventors to their metropolitan area of residence allowing for detailed spatial analysis (COMETS offers a different version of this).[51] A metropolitan area time series is thereby available.
- It provides a large number of "quality" metrics for each patent. Those emphasized in this report are claims and citations. **Claims** define the patent's invention and what is legally enforceable about it; patents with multiple distinct inventions enumerate multiple claims.[52] **Citations** to a patent are made if subsequent patents utilize relevant or related knowledge, as determined by the applicant (who is legally bound to mention such references) and the examiner. Both measures are widely acknowledged as indicating value in the academic literature on patents.
- Each patent has a USPTO technology code (class number), as well as a more aggregate classification and sub-classification scheme created by Strumsky, which provides a sense of the industrial orientation of each patent.
- Patents are linked to inventors and patent owners (assignees), thereby allowing researcher to match inventor address information to assignees to calculate ownership statistics by metropolitan area and according to different technological categories.
- Government grant funding is indicated using information on the patent record.
- Universities, government agencies, foreign and domestic individuals and corporations are identified as distinct categories of assignees.

Patent data was combined with other public data sources for the United States and all of its 366 metropolitan areas, which are statistical approximations of local and regional labor markets (e.g. a city and its suburbs). In the United States, Metropolitan Statistical Areas are defined by the U.S. Office of Management and Budget (OMB) based on data gathered by the Census Bureau. OMB locates these areas around a densely populated core, typically a city, of at least 50,000 people. Counties that have strong commuting ties to the core are then included in the definition of the metropolitan area.[53]

Focusing on the period from 1980 to 2010, the main measure of metropolitan economic performance used here is productivity, measured as value-added (or GDP) per worker. Unemployment rates were also analyzed as an outcome variable. In order to explain productivity and unemployment trends in metropolitan areas, a number of control variables were analyzed alongside patenting levels (the number of patents invented in a metropolitan area) and rates (patents invented per worker). These variables include population, the share of adults with a bachelor's degree or higher, the share of workers employed in the tech sector (see appendix for definition), housing prices, and the level of productivity predicted by a metro area's industrial mix and national averages of productivity in those sectors (i.e. predicted productivity). The motivation for using this variable is that it captures the effect of national productivity trends on metropolitan industrial sectors, and thus makes places like New York (with a large financial sector) comparable to Las Vegas (which has a large hospitality sector).[54]

The econometric analysis predicts the outcome variables using independent variables measured ten years in the past to avoid bias from reverse causation. The analysis also includes metropolitan effects, to control for unchanging characteristics of metropolitan areas, such as weather, history, and political institutions, and decade effects to capture national trends (in commodity or stock market prices, for example) that affect all metropolitan areas.

The appendix discusses more specific details of the data and analysis. Otherwise, the sources for information introduced into the text below are cited either directly or through endnotes. Much of the summary data here will be made available on the Brookings website at the report's homepage.

Findings

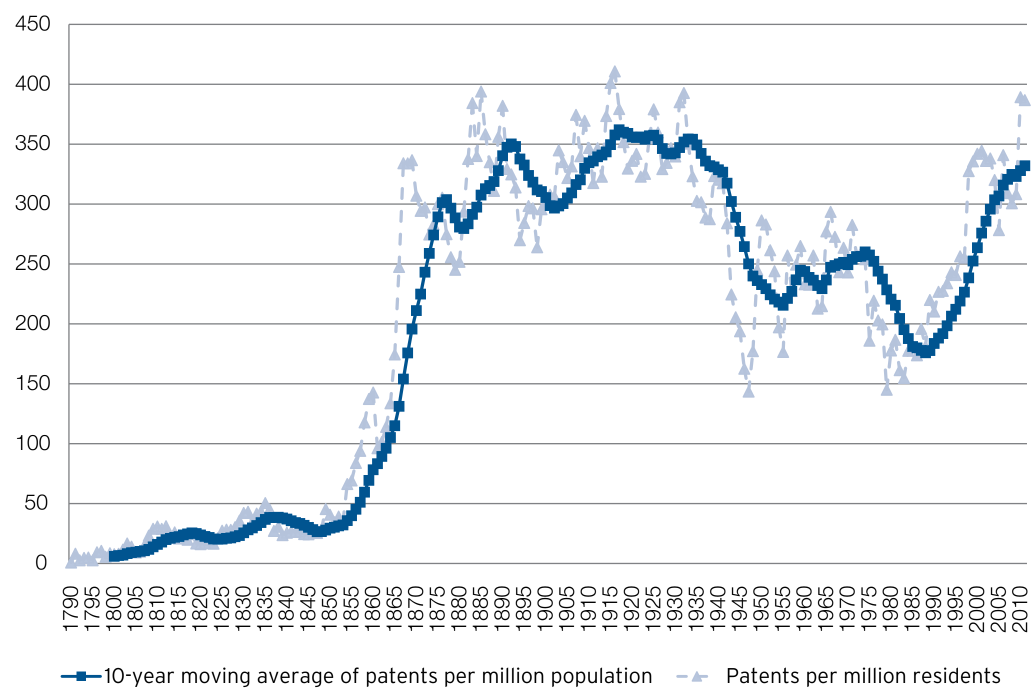
The rate of patenting in the United States has been increasing in recent decades and stands at historically high levels.

Though the United States was still recovering from the Great Recession, 2011 marked a new record high for the number of patents granted by the USPTO for both foreign and domestic-based inventors.[55]

As noted earlier, some economists and scholars have argued that invention is harder today than ever before because the "low-hanging fruit" has already been plucked. Yet, even if this is true, there are more scientists working today than ever before and research and development (R&D) spending is at an all time high. Science professors, engineers, and scientists comprised less than 1 out of every 1000 U.S. workers in 1910, but 25 out of every 1000 in 2010.[56] Perhaps, that is why the rate of patenting is nearly as high today as any point in U.S. history, as Figure 1 demonstrates covering 212 years of invention.

To be more exact, consider the 10 most inventive years in U.S. history, measured by patents per capita. The data excludes patents granted to foreign inventors. They are 1916, 1915, 1885, 1932, 2010, 2011, 1931, 1883, 1890, and 1917. In other words, two of these years came just after the Great Recession. The others were in the midst of the Industrial Revolution and post-Civil War America.

Figure 1. History of Patented U.S. Inventions per Capita, 1790–2011 by Year Granted



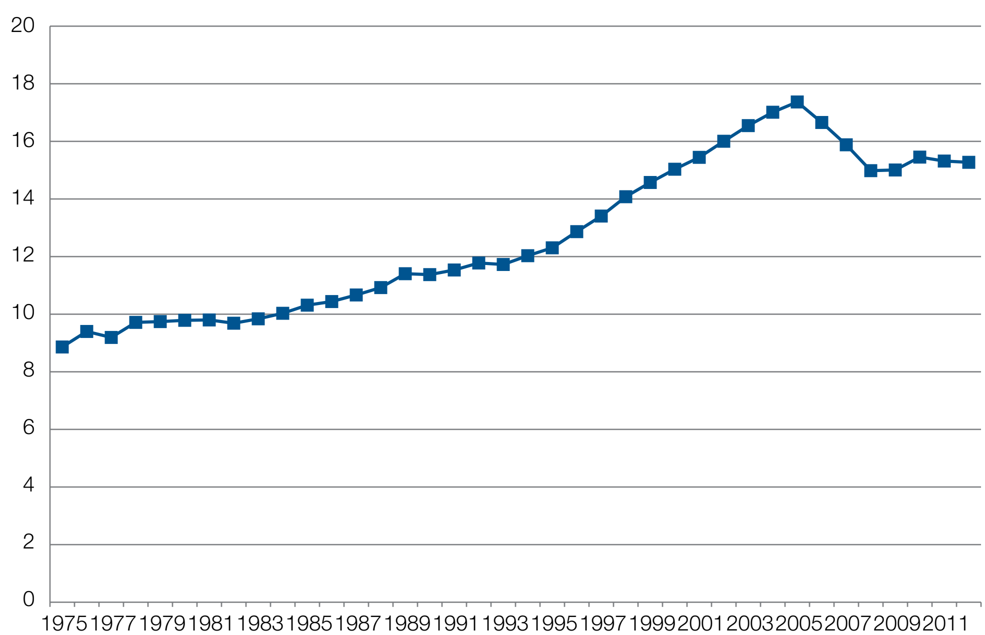
Stepping back, one can pick out a few eras of U.S. inventiveness. From 1790 to 1853, the rate of invention was very low, but it exploded in the Industrial Revolution starting in the mid-19th Century and lasting all the way until the Great Depression. Scholars have characterized this period of U.S. history as the "golden age" of invention when industries such as textiles, garments, household utensils, and farming implements experienced tremendous innovation.[57] With the onset of the Great Depression, the rate of invention plummeted from the 1930s to 1955, but there was a noticeable post-war rebound from 1956 to 1973, when the major research breakthroughs in modern information technology were first made. The decade from 1974 to 1984 saw a precipitous decline in inventive activity, but since, then, and starting in 1985, a post-industrial era of invention has begun and patent rates have steadily increased and remained high.

There was one exceptional period with respect to this current trend towards higher patenting rates. The years from 2002 to 2005 saw one of the largest four-year drops in patent per capita since the Civil War—a decline of 17 percent, compared to a 2 percent increase for the average four year period since 1870. This was the height of the investment bubble in subprime mortgages, but this drop off also reflects slowed application growth from 2001 to 2002 in the wake of the IT-bubble. Still, patent growth has been very strong since the Great Recession officially ended in 2009. The data in Figure 1 refer to granted patents by the year they were granted, which has been 3 to 4 years after its application in recently, but the trend is similar for applications; patent application growth was zero from 2007 to 2009 but accelerated to 7 percent from 2009 to 2010 and 3 percent from 2010 to 2011. One would, therefore, expect a spike in grants in 2013.

Scholars have noted the strong growth in patenting over the last two decades. Some have argued that it is the result of changes in patent law, particularly changes that allowed for software patents, or a relaxation of standards. In other words: Has quantity been achieved at the expense of quality?

There is evidence here to suggest otherwise. As others have found, objective measures of patent quality have been increasing in recent decades, such as the number of claims per patent.[58] The trend is illustrated in Figure 2. The number of claims per patent has increased steadily since 1975 and reached a high point in 2005 at 17.4. The measure declined during 2006 and 2007 and started

Figure 2. Trend in Claims and Citations (Within Eight Years of Grant) for all USPTO Patents Granted Between 1975 and 2012, by Year Granted



growing again in 2010. No recent decade has seen as many claims per patent as the 2000s. The slight dip in claims in recent years could be due to increases in the fees charged by the USPTO for over 20 claims.[59] Other scholars have found that the upward trend in claims is partly attributable to the internationalization of patent applications and the growing complexity of patenting, but much of the time trend cannot readily be explained.[60]

The increase in measured patent quality and patent rates coincides with an increase in R&D spending and does not appear to be entirely driven by legal changes, as patent scholars have noted.[61] Indeed, R&D expenditures, adjusted for inflation, increased by an annualized rate of 3.6 percent each year from 1980 to 2009, with roughly 70 percent coming from industry sources, and R&D spending since 1953 is highly correlated with patenting and the patent rate.[62] In 2008, inflation-adjusted R&D reached a record high, with 2009 as the last available year of data.[63]

If measured as a share of GDP, R&D spending has been more steady over the decades, but in 2009, the ratio—2.9 percent—equaled the historic high last achieved in 1964. R&D classified as basic, rather than applied or developmental, has increased the most rapidly since 1953.[64] The U.S. trend is less impressive, however, when compared to some other developed countries, when compared data is examined. From1981 to 2008, U.S. R&D growth was slower than a number of highly developed countries such as each of the Scandinavian countries, Spain, Australia, Canada, and Japan, though higher than many larger economies like Germany, the United Kingdom and France.[65]

The only modest relative growth in U.S. R&D may explain why, as noted in the introduction, the United States ranks just ninth in patents per capita, using appropriate international data. Patent scholars have noted a "home-office bias," meaning that European inventors tend to rely disproportionately on the EPO, Japanese inventors on the JPO, and US inventors on the USPTO.[66] The Organization for Economic Cooperation and Development (OECD), however, provides data on applications filed under the Patent Cooperation Treaty (PCT), which creates a universal application for patents that can be used across the major patent offices.[67] Such patents tend to be more valuable than those using only the domestic office applications.[68] This limits the comparison to potentially international patents. On this score the United States ranks ninth on patent applications filed under the PCT system from 2000 to 2010, below (in order from the highest) Sweden, Finland, Switzerland, Israel, the Netherlands, Denmark, Germany, and Japan. Using only 2010 data, the United States falls to 12th, as Korea, Norway, and Austria move ahead. The average Swede is roughly twice as likely to file a PCT application as the average American. Those U.S. rankings are identical using data on patents granted by the USPTO and filed at all three major offices (EPO, JPO, and USPTO).[69]

The inventions from these countries, on net, will likely benefit U.S. consumers, even as some companies and workers lose out from competition, but what is more troubling is that additional R&D spending has not translated into as many patents as one might have expected. Consistent with the concern that technologies are becoming more complex, fewer inventions are patented for every dollar of R&D. From 1953 to 1974, one patent was generated for every $1.8 million of R&D. Since 1975, the average implicit "cost" has been $3.5 million, about twice as high, in inflation adjusted dollars. As other scholars have found, the increased cost of R&D per patent could be at least partly attributed to an increase in quality, but it means R&D growth must accelerate.[70]

The trend in R&D and claims suggest that the increase in the patenting rate may reflect a real increase in the number of valuable inventions. Skeptical readers, however, may still want further evidence that the trend is not the result of relaxed approval standards, a surge in foreign-inventor contributions, or the perverse incentives of litigation. While these and other explanations cannot be definitely rejected, the broad evidence is consistent with the conclusion that the rate of invention is increasing along with the rate of patenting. The share of patents that have received no citations—which does not necessarily indicate that they are or poor quality—has held steady between five and six percent in the 1980s and 1990s.[71] Moreover, while the share of USPTO patented granted to foreign inventors has increased dramatically (and is now almost half), those granted to domestic inventors make significantly more intellectual property claims and receive more subsequent citations by a wide margin, as Table 1 displays.

It is also unlikely that changes in litigation practice explain the increased patenting rate. Annualized growth in re-examinations from 1981 to 2011 was 4.9 percent compared to 4.8 percent patent growth.[72] Median damages amounted to $2 million in 2010, according to one study, but there was no upward

Table 1. Intellectual Property Claims and Citations Within Eight Years of Grant by Foreign Status of Inventor, for All Granted Patents Applied For, 1975–2012

	Claims	Citations within 8 years
U.S. Inventors	15.1	8.0
Foreign Inventors	12.1	5.1

Source: Brookings analysis of Strumsky patent database

Table 2. Claims per Patent, and Eight-Year Citations per Patent, in the 10 Largest Subcategories

Subcategory	Annual Granted Patents, applications from 2006-2010	Claims per patent, applied for from 2006-2010	Citations per patent, applied for from 1991-1995
Communications	10,711	17.2	16.0
Computer Software	8,395	17.5	18.9
Semiconductor Devices	8,258	14.2	14.1
Computer Hardware & Peripherals	7,327	16.1	16.2
Power Systems	6,904	11.7	9.4
Electrical Systems & Devices	5,540	13.8	8.0
Biotechnology	5,189	15.3	7.0
Measuring & Testing	4,652	13.5	7.2
Information Storage	4,626	15.6	11.8
Transportation	4,533	9.0	6.6
10 largest subcategories	**66,134**	**14.4**	**11.5**
All subcategories	**138,312**	**12.8**	**9.8**

Source: Brookings analysis of Strumsky patent database. Patents years are determined by year of application. Each period observation is the average of the five year period ending that year. The subtotal and total rows display totals in the first column and un-weighted averages in the second and third columns.

trend compared to recent years.[73] While litigation has been increasing, the rate of growth is consistent with the rate of growth in patenting. The number of patent cases filed at U.S. District Courts as a percentage of all patents remained stable from 1970 to 2008.[74] The rate has hovered between 1.2 and 1.6 percent of patents granted.[75] By historic standards, this is actually not particularly high, though comparisons across different institutional arrangements and eras are subject to considerable error. In the early years of the industrial revolution, the rate was as high as 3.6 percent in the 1840s and 2.1 in the 1850s; many disputes concerned manufacturing industry inventions, the tech sector of the 19th century.[76] Before Bell Labs established itself as the darling of invention, Alexander Graham Bell won large patent infringement cases in the 1870s.[77] Likewise, industrial giants GE, founded by Thomas Edison, and Westinghouse filed hundreds of patent suits in the 1890s.[78] None of this is to suggest that the threat of law suits or the trend in undisclosed settlements have not increased or that of the patent system's rules are optimal.[79]

To better understand patenting trends, one can start by looking at which technologies are represented in patents. First of all, almost half (46 percent) of all patents can be grouped in the 10 largest categories; the patents in this group tend to make more claims and receive more citations compared to smaller technological groups, which may or may not reflect underlying value.

The most prominent technological category is communications. Over the five year period ending in 2010, 10,000 patents were granted to communications technologies, and as Table 2 shows, these patents were also highly valuable in terms of claims and citations. Leading patent owners over the five year period include Cisco, IBM, AT&T, Qualcomm. Two of the next four categories are directly linked to computers—software (e.g. Microsoft) and hardware (e.g. Apple), and also score highly on citations and

Table 3. Subcategories with the Fastest and Slowest Growth Rates in Patenting from 1980 To 2005, by Change in Value Measures

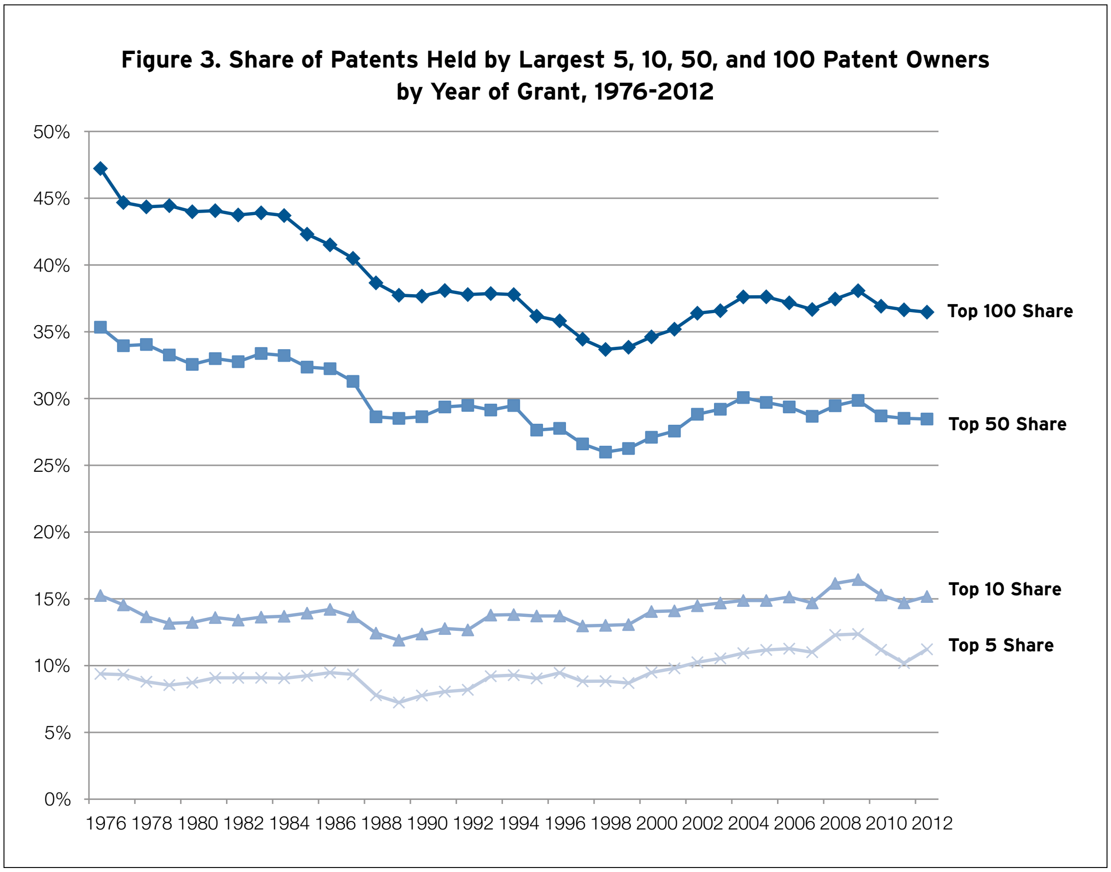
Subcategory	Annual Growth Rate in Patents, 1980-2005 (moving average)	Change in Claims per Patent, 1980 to 2005	Change in Eight- year Citations per Patent, 1980 to 1995
Subcategories with the fastest growth in patents			
Computer Software	11%	7.3	12.1
Data Processing	11%	6.3	11.0
Semiconductor Devices	10%	6.0	8.1
Video Distribution Systems	10%	7.0	36.1
Computer Hardware & Peripherals	8%	7.0	9.2
Chemical-Crystals	8%	5.4	7.6
Nanotechnology	8%	10.3	5.5
Information Storage	6%	7.3	6.8
Communications	6%	8.4	11.7
Design	5%	0.0	2.4
Subcategories with the slowest growth in patents			
Chemical-Purification/Evaporation/Distillation	-2%	6.0	3.6
Chemical-General Compound & Compositions	-3%	5.4	3.0
Time Measurement & Horology	-3%	5.1	3.1
Machine Element or Mechanism	-3%	5.7	2.9
Chemical-Manufacture Specific	-3%	7.5	3.9
Organic Compounds	-3%	5.0	2.5
Pipes & Joints	-3%	5.2	3.1
Education & Demonstration	-4%	7.4	10.9
Hazardous Waste	-4%	5.7	0.5
Heating, Refrigeration & Ventilation	-4%	6.8	2.8

Source: Brookings analysis of Strumsky patent database. Patents years are determined by year of application. Each period observation is the average of the five year period ending that year.

claims. In general, the computer and information technology patents tend to make the most claims and receive the most citations; the large number of citations may reflect the large scale of the industry's patenting activities, which would require documenting previous work.

Other large technological groups tend to receive fewer citations and make fewer claims, but nonetheless make large contributions to U.S. and global invention, including a number of older industrial categories related to power, electrical systems, measuring devices, and transportation. For Electrical Systems and Devices, some of the leading owners of patents granted between 2006 and 2010 were IBM, Tyco Electronics (now TE Connectivity), Intel, Broadcom, Texas Instruments, Micron, and the Eaton Corporation. Transportation includes the auto and aerospace industries, with prominent patent owners including Goodyear, Ford, GM, Boeing, Honda, Delphi, Lockheed Martin, and Caterpillar. Large inventors of Power Systems patents include GE, IBM, GM, HP, Lutron Electronics, and Honeywell. Leading Measuring and Testing patent owners include some lesser known companies like KLA-Tencor, Schlumberger, Agilent, Applied Materials, and Zygo.

Table 3 reports the technological categories with the strongest and weakest growth rates in patenting from the five year period ending in 1980 to the five year period ending in 2005. Again information and communication technologies are among the strongest growing technological categories, led by Computer Software, Data Processing, Video Distribution Systems, Computer Hardware, Information Storage, and Communications. Computer and information related technologies have also seen sharp increases in claims and citations per patent. The Nanotechnology category is not frequently used by the patent examiners, considering that it has less than 1000 total patents, but it has been growing rapidly in recent years. It refers mostly to microscopic measurement devices. The Design category refers



to the design aspects of miscellaneous machines and cosmetic products, with leading patent owners including Black and Decker, Procter and Gamble, and Gillette.

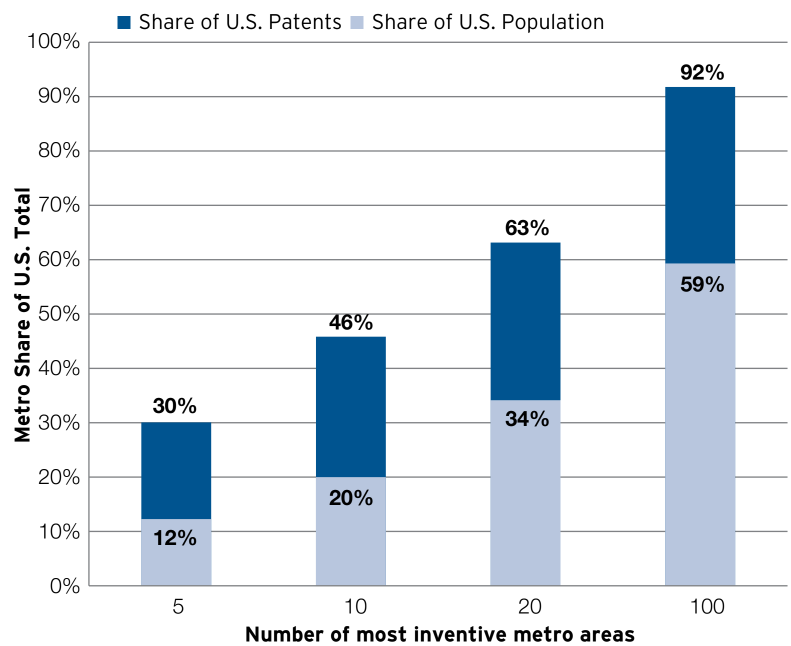
One implication of the industry category analysis becomes clear: Most patents, especially of higher value, are being generated by a small number of industries, disproportionately and primarily in fields like computer and information technology, electronics, biotechnology, energy, and transportation. As a recent report from the USPTO documented, patent intensive industries employ just a small fraction of the U.S. workforce, and yet these industries drive most of the technological changes that increase living standards, by reducing the costs of things like food, energy, and information.[80]

Yet, that industry concentration has not coincided with limited competition. As Figure 4 shows, patent ownership has become more dispersed since the mid 1970s and 1980s, at least outside the very largest firms. The share of patents held by the top 5 patent owning companies has increased slightly from 9 percent in 1976 to 11 percent in 2012, but the top 10 share has remained stable, and the top 50 and top 100 shares have fallen by 7 and 11 percentage points respectively. The trend is similar even in the more concentrated and controversial category of software patents.

Even these data understate the creative destruction of high-tech companies for the list of companies at the top has changed. In recent years (2011 and 2012), just 4 of the top 10 owners of patents granted those years were in the top 10 between 1976 and 1980: IBM, GE, GM, and AT&T (counting Bell Labs as the antecedent). Of the rest, Hewlett-Packard cracked the top 10 for the first time in 1992, Microsoft and Intel in 1996, Cisco in 2006, Broadcom in 2009, and Apple not until 2010. In other words, even while a few tech giants account for a large share of the nation's patents, patent ownership as a whole has become broader and more competitive with considerable churn both at the top and throughout the distribution, including a massive increase in the number of firms with just one patent per year. In 1976, 2,677 companies or organizations (like universities or federal agencies) owned exactly one patent granted that year; by 2011, that number had soared to 9,909.

From 1980 to 2011, the average metropolitan area saw a 7 percentage point drop in the share of newly granted patents held by the largest patent owner and a 2 percentage point drop in the share

Figure 4. Concentration of U.S. Patents Invented in Most Inventive Metro Areas from 2000-2012 Relative to 2010 Population Shares



held by the top 5 assignees. Many high patenting metropolitan areas saw patents disperse widely across firms. In Indianapolis, for example, there was a 29 percentage point decrease from 1980 to 2011 in the share of patents owned by the top 5; in Boulder, Colorado there was a 27 percentage point decrease; a 17 percentage point decrease in Austin, and an 8 percentage point decline for San Francisco. In general, the more patents in a region, the wider the dispersion across firms at any given time.

To summarize this section, patent data implies that the rate of invention—at least of patentable inventions—is near historic highs, quality appears to be increasing and not as the result of changes in litigation practices, a few industries are responsible for most patenting activity, and competition between patent owners seems to have increased.

Still, give the geographic concentration of industries and production, the gains from patenting may be similarly concentrated and of little benefit to large numbers of Americans. For all the dispersal of invention, relative to the hierarchical corporate labs of the 1970s, there remains a massively unequal distribution of patents across metropolitan areas. The next sections turn to the spatial geography of patenting and its effect on economic performance.

Most U.S. patents—63 percent—are developed by people living in just 20 metro areas, which are home to 34 percent of the U.S. population

Metropolitan areas play a critical role in setting the productivity of the U.S. economy.[81] Large metros in particular account for a disproportionate share of GDP and educated workers, but they are especially crucial for patenting. The 100 largest metro areas are home to 65 percent of the U.S population in 2010, but they are home to for 80 percent of all U.S. inventors of granted patents since 1976 and 82 percent since 2005. Few patents are invented outside of metro areas. In fact, 93 percent of all U.S. patent inventors have lived in metro areas since 1976 (using the year of application).

U.S. patented invention is highly concentrated in a relatively small number of cities and their suburbs, as Figure 1 reinforces. Indeed, just the five most patent intensive metro areas accounted for 30 percent of all patents from U.S. inventors. The average resident in these five metro areas is 2.4 times

Table 4. Total Granted Patents and Patenting Rate by Metropolitan Area of Inventor, 2007–2011

	Average Granted Patents per year, 2007-2011	Patents per million residents, 2007-2011	Largest subcategory of patents
San Jose-Sunnyvale-Santa Clara, CA	9,237	5,066	Computer Hardware & Peripherals
San Francisco-Oakland-Fremont, CA	7,003	1,638	Biotechnology
New York-Northern New Jersey-Long Island, NY-NJ-PA	6,907	366	Communications
Los Angeles-Long Beach-Santa Ana, CA	5,456	424	Communications
Seattle-Tacoma-Bellevue, WA	3,968	1,174	Computer Software
Boston-Cambridge-Quincy, MA-NH	3,965	877	Biotechnology
Chicago-Joliet-Naperville, IL-IN-WI	3,886	409	Communications
San Diego-Carlsbad-San Marcos, CA	3,165	1,041	Communications
Minneapolis-St. Paul-Bloomington, MN-WI	3,068	945	Surgery & Medical Instruments
Detroit-Warren-Livonia, MI	2,720	621	Transportation
Austin-Round Rock-San Marcos, TX	2,497	1,503	Computer Hardware & Peripherals
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	2,370	402	Biotechnology
Houston-Sugar Land-Baytown, TX	2,202	379	Earth Working & Wells
Dallas-Fort Worth-Arlington, TX	1,945	310	Communications
Portland-Vancouver-Hillsboro, OR-WA	1,844	837	Computer Hardware & Peripherals
Atlanta-Sandy Springs-Marietta, GA	1,506	285	Communications
Washington-Arlington-Alexandria, DC-VA-MD-WV	1,479	271	Communications
Phoenix-Mesa-Glendale, AZ	1,437	343	Semiconductor Devices
Raleigh-Cary, NC	1,273	1,164	Computer Hardware & Peripherals
Poughkeepsie-Newburgh-Middletown, NY	1,226	1,829	Semiconductor Devices
Average of all metropolitan areas	299	296	

Source: Brookings analysis of Strumsky Patent Database and American Community Survey. One patent is assigned to a metro area if at least one inventor lives there. Year refers to year of application, not grant. Since it takes a few years for an application to become granted, these patent totals are artificially low.

more likely to invent a patent than the average American. The 10 most inventive metro areas account for nearly half of all patents, 46 percent, and the 100 most inventive metros account for 92 percent. These metro areas contain a hugely disproportionate number of highly specialized researchers, engineers, and entrepreneurs who are coming up with new technologies.

This degree of concentration has not changed much since the 1980s, though two trends are worth noting. The concentration of patents in the 100 most inventive metro areas has increased from 90 in the 1980s to 92 (since 2000), even as the share concentrated in the top five fell from 32 to 30. In other words, invention is slightly more concentrated in large metro areas than it was three decades ago, but the dominant regions have lost market share to other highly inventive areas.

From 1980 to 2011, a few large metros notably changed their share of U.S patents.[82] At the top, San Jose moved up from ninth to first, and San Francisco moved from seventh to fourth, moving ahead of Chicago, Philadelphia, Detroit, and Boston. Seattle and San Diego moved up 15 and nine places, respectively, to become seventh and eighth. Meanwhile, Austin and Raleigh moved up 41 and 55 places, respectively, to become 11th and 20th. Cleveland fell 10 slots from 13th to 23rd, while Philadelphia fell from fourth to 13th.

Although the high-patenting metro areas are all large, patenting per capita rates (a measure of the inventive productivity of an area) vary widely. Table 4 lists the metro areas of any size with the highest number of granted patent over the five year period ending in 2011. In the last column, the largest patenting subcategory is listed for each metro to provide a sense of the most prominent patenting industries.

With computer hardware and peripherals as the lead category, San Jose stands out with 9,237 patents per year, from 2007 to 2011. This is 2000 more patents than the next highest metro area—its neighbor, San Francisco. Of the other large metros on the list, New York, Chicago, Washington D.C.,

Table 5. Total Granted Patents and Patenting Rate by Metropolitan Area of Inventor, 2007–2011

	Patents per million residents, 2007-2011	Average Granted Patents per year, 2007-2011	Largest subcategory of patents
San Jose-Sunnyvale-Santa Clara, CA	5,066	9,237	Computer Hardware & Peripherals
Burlington-South Burlington, VT	3,951	826	Semiconductor Devices
Rochester, MN	3,300	606	Computer Hardware & Peripherals
Corvallis, OR	2,319	194	Semiconductor Devices
Boulder, CO	2,274	666	Communications
Poughkeepsie-Newburgh-Middletown, NY	1,829	1,226	Semiconductor Devices
Ann Arbor, MI	1,697	590	Motors, Engines & Parts
San Francisco-Oakland-Fremont, CA	1,638	7,003	Biotechnology
Austin-Round Rock-San Marcos, TX	1,503	2,497	Computer Hardware & Peripherals
Santa Cruz-Watsonville, CA	1,204	310	Computer Hardware & Peripherals
Seattle-Tacoma-Bellevue, WA	1,174	3,968	Computer Software
Raleigh-Cary, NC	1,164	1,273	Computer Hardware & Peripherals
Rochester, NY	1,149	1,198	Optics
Durham-Chapel Hill, NC	1,120	552	Biotechnology
Trenton-Ewing, NJ	1,073	393	Biotechnology
Sheboygan, WI	1,045	120	Invalid USPTO Code
San Diego-Carlsbad-San Marcos, CA	1,041	3,165	Communications
Albany-Schenectady-Troy, NY	981	846	Power Systems
Ithaca, NY	959	97	Biotechnology
Minneapolis-St. Paul-Bloomington, MN-WI	945	3,068	Surgery & Medical Instruments

Source: Brookings analysis of Strumsky Patent Database and American Community Survey. One patent is assigned to a metro area if at least one inventor lives there. Year refers to year of application, not grant.

Miami, and Atlanta have rather low patenting rates—less than 10 times the rate of invention in San Jose. On the other hand, San Francisco, Boston, Austin, Seattle, San Diego, Portland, Rochester, and Minneapolis are in an upper tier of large metros that produce patents at high volumes and rates.

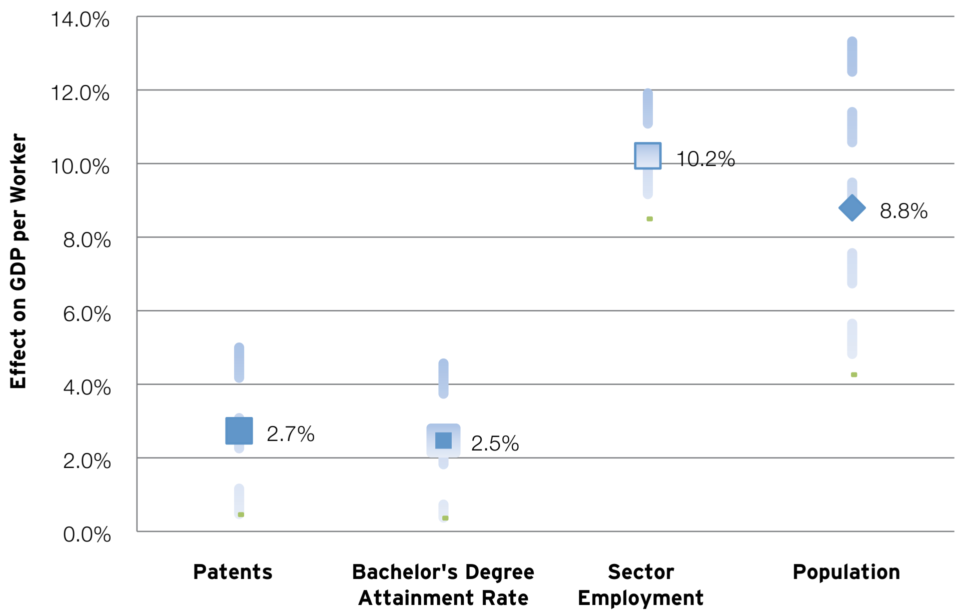
Many of the metro areas just mentioned also develop patents at extraordinarily high rates, especially San Jose; with over 5,000 patents per million residents in any given year from 2007 to 2011 it is the most inventive metro area by size and intensity. As Table 5 shows, highly inventive metro areas are scattered across each region of the country. In the Northeast there is Burlington, Vermont, one in New Jersey (Trenton in Mercer County, which includes Princeton), and three more in New York. The West is represented by 7 of the top 20 metro areas, including 4 in California, as well as Corvallis, Oregon, Seattle, and Boulder Colorado. The Midwest has four—with Rochester, Minnesota rating the highest—and the south three, with Austin, Texas and two in North Carolina.

The differences in patenting rates are truly large, when metro areas at the extremes are placed side by side. A resident living in one of the 100 most inventive metropolitan areas is seven times more likely to invent a patent than someone living in lower ranked metropolitan area. A resident of the San Jose metropolitan area is 600 times more likely to invent a patent than a resident of McAllen, Texas, 160 times more likely than a resident of Johnstown, Pennsylvania, and 100 times more likely than residents of Fresno, California or Lakeland-Winter Haven, Florida. Even compared to a high-patenting area like metropolitan Detroit, a San Jose resident is 8 times more likely to invent.

Inventions, embodied in patents, are a major driver of long-term regional economic performance, especially if the patents are of higher quality.

It is well documented that inventors and companies do not benefit from the full value of their products.[83] Much goes to consumers or society, in form of better health and higher quality, more affordable goods and services. Regions too are unlikely to capture the full benefits of ideas invented there that

Figure 5. Average 10-Year Marginal Effect of Metro Area Patents and Other Variables on Total Metro Area Productivity Growth, with 95 Percent Confidence Intervals, 1980-2010



eventually become commercialized, traded, implemented, and perhaps even copied. With this in mind, the question arises: Do regions benefit from having many inventors?

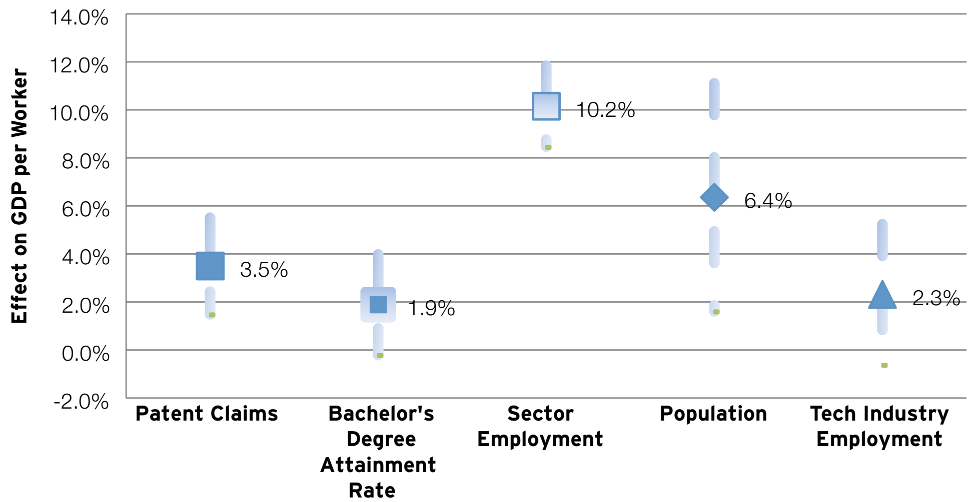
To answer this question, regression analysis was used to assess the relationship between patents and productivity growth—measured as GDP per worker—from 1980 to 2010 for every metropolitan area in the United States (with available data that came to 358). Since many other factors affect productivity but might be correlated with patenting, the analysis controls for the share of college graduates living in the metro area, population size, industry concentration, housing prices, and constant metropolitan specific characteristics (which would include geographic advantages, history, and political institutions). The econometric details are shown in the appendix

The results clearly show that patenting is associated with higher metropolitan area productivity. The analysis cannot rule out that the link is caused by some missing variable or reverse causality, but given the control variables and the fact that patents were lagged ten years in the analysis, the most likely explanation is that patents cause growth. In order to translate the evidence into concrete terms, one can group metropolitan areas into quartiles of patenting, with the most inventive metros (by number of patents) in the top quartile.

If the metro areas in the lowest quartile, patented as much as those in the top quartile, they would boost their economic growth by 6.5 percent over a ten year period. By comparison, the average metro area in this bottom quartile grew by 13 percent each decade over this period, so an extra 6.5 percent would be a large boost, representing an extra $4,300 per worker (adjusted for inflation). That would require, roughly, an extra 960 patents per year. Though not without difficulty, such figures could be generated by a few large corporate R&D offices or universities.

The other notable finding is that patents compare rather well to other growth-enhancing factors, like human capital. First of all, five variables analyzed in this analysis are all statistically significant and economically meaningful. With that said, the patenting effect is somewhat larger than the effect from bachelor's degree attainment. A one standard deviation of growth in the number of patents (or, more precisely, the natural log of patents) granted to metro area inventors is associated with a 2.7 percent increase in economic growth—measured as output per worker. That compares to 2.5 percent for a one

Figure 6. Average 10-Year Marginal Effect of Metro Area Claims and Other Variables on Total Metro Area Productivity Growth, with 95 Percent Confidence Intervals, 1980-2010



standard deviation increase in the bachelor's degree attainment rate and slightly less for the sector employment effect.

The patenting effect is important, but it is smaller than the effects from population size and sector employment concentrations. The sector effect is the largest. The interpretation is intuitive: Where employment is concentrated in high-productivity industries (e.g. energy, utilities, finance, information, and professional services), metropolitan area output per worker is consistently higher. Where it is in low-productivity sectors---like health care, leisure and hospitality (tourism), education, restaurants, and agriculture—metro area productivity is low.

Population also has a large effect on productivity. This is the well documented phenomena that firms are more productive when they exist in clusters of related businesses and in large urban areas.[84]

Patenting Quality

Patent claims have a larger effect on metropolitan productivity than patents themselves. This makes sense if one considers that a patent with many claims is akin to multiple patents with few claims. In fact, after accounting for the number of claims, patents do not add value to a metropolitan economy.

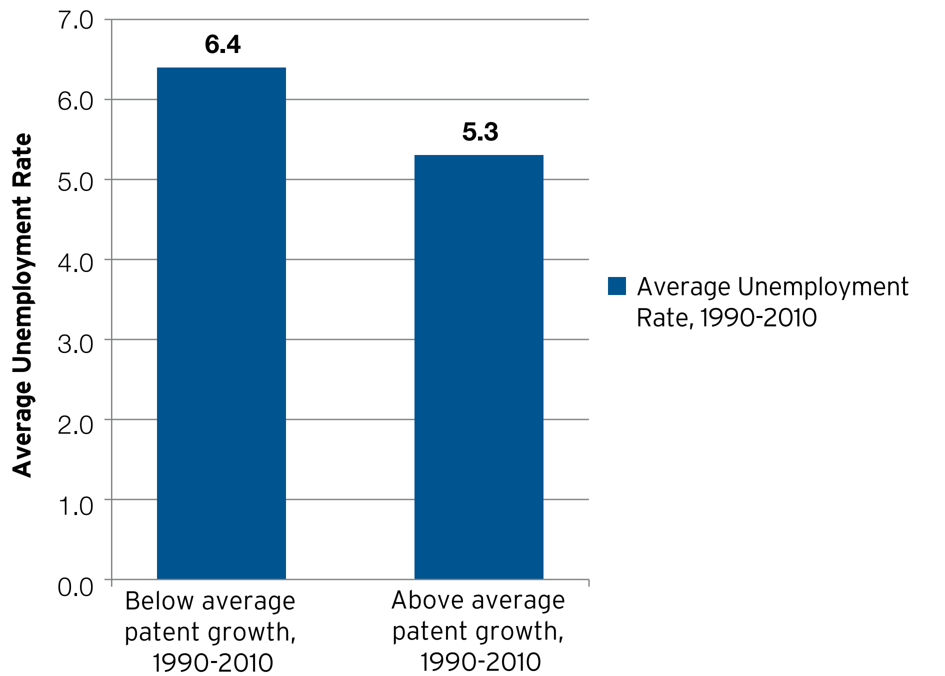
To test the strength of these conclusions, the analysis also considered the effects of employment in tech industries, which are high-patent industries. The motivation for this is that tech sector workers and their companies may have other characteristics—besides high patenting rates—that are associated with productivity (e.g. higher education levels, export orientation, and wages).[85]

The effects of patent claims are compared to other variables, as was done above with patents, in Figure 7, shown above. Patent claims are highly significant and strongly associated with productivity growth. Industrial sector and population effects are larger, though the effects of population and patent claims overlap, so one cannot be sure that they differ. Meanwhile, bachelor's degree attainment is now marginally insignificant, as is tech-sector employment. They are highly correlated, and further analysis shows that their combined effect is highly significant.[86]

Metropolitan Level Trends in Productivity

The aggregate results reported above become more concrete when looking at specific metropolitan areas. Table 6 lists the large metropolitan areas with the largest increase in patents per worker from 1980 to 2010, along with their performance on productivity growth, the change in the bachelor degree

Figure 7. Average Unemployment Rates of Metropolitan Areas with Above and Below Average Growth in Patents from 1990 to 2010



attainment rate, and growth in predicted productivity (based on how national trends in sector productivity would be expected to affect metro areas, given their sector mix).

San Jose, again, tops the list, with an increase of 13,206 patents per million workers from the 1980 to 2010. Stated otherwise, the probability that a given worker in San Jose invented a patent increased by 1.3 percentage points—and the increase will be even higher as pending patents become granted in the next few years. As it happens, San Jose also experienced the highest productivity growth, and much of that growth cannot be explained by its re-orientation towards more productive economic sectors, as a comparison between the second and the third columns suggests.

Patenting is correlated with productivity growth: 14 of the 20 metro areas with the largest increase in patents per worker from 1980 to 2010 (out of the 358 with complete data) experienced above average productivity growth. Indeed, in addition to San Jose, four of those other metro areas are also ranked in the top 20 on productivity growth: Corvallis, OR; Boulder, CO; Raleigh, NC; and Portland, OR. In each case, sector re-orientation towards higher-productivity industries would predict lower growth rates than they actually experienced, suggesting that other factors were at work. In addition to explosive patent growth, Raleigh and Boulder had rapid increases in human capital, measured by the share of adults aged 25 and older with a bachelor's degree or higher, but this was not the case in Corvallis and Portland, where the increase in bachelor degree attainment shares was below average.

For the six metro areas with a large patent increase but low productivity growth, five of them shifted employment towards low productivity but stable economic sectors like education and health care (e.g. in Provo, home to BYU, 22 percent of workers were employed in education and health care, compared to 14 percentage nationally). The other—Racine, Wisconsin—suffered from stagnant population growth and a meager increase in the bachelor's degree attainment rate.

The same relationship between patents and productivity changes can be drawn by examining metropolitan areas with that developed fewer patents per worker over the three decades. Rust belt metro areas with low productivity growth—like Pittsburgh, Toledo, and Buffalo—actually saw a decrease in the number of patents per worker. This is also true of Tulsa, Oklahoma, Louisville, and Baton Rouge, all

Table 6. Productivity Growth in the 20 Metropolitan Areas with the Largest Increase in Patents per Worker, 1980–2010

	Change in patents per million workers, 1980-2010	Annual Productivity Growth, 1980-2010	Predicted Productivity Growth, 1980-2010	Change in Bachelors Degree Attainment 1980-2010
San Jose-Sunnyvale-Santa Clara, CA	13,206	3.3%	2.2%	18.4%
Burlington-South Burlington, VT	8,355	2.1%	1.7%	16.6%
Corvallis, OR	6,644	2.6%	1.1%	11.3%
Winchester, VA-WV	6,633	1.6%	1.6%	10.5%
Rochester, MN	6,536	1.6%	0.9%	14.0%
Charlottesville, VA	4,491	1.4%	1.4%	15.1%
Poughkeepsie-Newburgh-Middletown, NY	4,219	1.8%	1.4%	12.7%
San Francisco-Oakland-Fremont, CA	4,059	1.9%	1.2%	17.5%
Blacksburg-Christiansburg-Radford, VA	3,709	1.3%	1.2%	11.5%
Austin-Round Rock-San Marcos, TX	3,591	1.9%	1.3%	12.8%
Santa Cruz-Watsonville, CA	3,547	1.7%	1.1%	13.7%
Boulder, CO	3,182	2.3%	1.8%	20.6%
Seattle-Tacoma-Bellevue, WA	2,957	1.3%	1.5%	14.8%
Raleigh-Cary, NC	2,848	2.3%	1.9%	19.8%
Ann Arbor, MI	2,602	1.1%	1.5%	14.7%
San Diego-Carlsbad-San Marcos, CA	2,357	2.2%	1.3%	13.1%
Durham-Chapel Hill, NC	2,212	1.9%	1.5%	17.8%
Provo-Orem, UT	2,062	0.5%	1.3%	12.0%
Portland-Vancouver-Hillsboro, OR-WA	2,056	2.5%	1.3%	13.9%
Racine, WI	2,046	1.0%	1.8%	9.0%
Average for top 20 metros	**4,366**	**1.8%**	**1.5%**	**14.5%**
Average of all metro areas	**395**	**1.4%**	**1.4%**	**9.7%**

Source: Brookings analysis of Strumsky database, U.S. Census Bureau, and Moody's Analytics. Patent totals for 1980 and 2010 are based on five year moving averages that end in those years, since patent data fluctuates from year to year. Figures are based on application year of patents already granted. Predicted industry productivity multiplies metro area employment shares by sector by national productivity for each sector. The growth rate is calculated using 1980 and 2010 measures.

three of which had very slow productivity growth.

On the other hand, a metropolitan area like Detroit does not fit the model in any simple way. It ranked 37th on the increase in patents per worker, but 306th in productivity growth, 185th on predicted productivity growth, 248th on tech sector job growth, and 316th on population growth. Here, the outsourcing of production to the U.S. South and other countries is likely a major factor. The case of Detroit serves as a warning that patenting alone will not guarantee prosperity; rather it must be combined with other pro-growth attributes that Detroit evidently has been lacking.

Invention and Unemployment in Metropolitan Areas

While granting that patents add value to a regional economy, some may be concerned about how technology-led productivity growth affects labor demand, since new technologies require few workers.[87] On the other hand, more productive metro areas have more money available to spend on local services, which should boost job creation.

This analysis finds that patent growth is strongly correlated with better employment opportunities. From 1990 to 2010, metro areas with faster growth in patenting had significantly lower average unemployment rates during those two decades. The analysis, which is summarized in Figure 8, was conducted using all metro areas and controlling for changes in college educational attainment rates, population growth, housing price growth, tech sector growth, and predicted industry growth. (The results are shown in more detail in Appendix Table 2). Focusing on just the 100 largest metro areas for ease of comparison, lists those with the highest and lowest patent growth rates.

Table 7. Average Unemployment Rates from 1990 to 2010 and Patent Growth in the 100 Largest Metro Areas

	Unemployment Rate, average 1990-2010	Patent Growth, annual average 1990-2010	Change in share of population with Bachelor's or higher, 1990-2010	Job growth, annual average 1990-2010
Metro Areas with the highest growth in patents from 1990 to 2010				
Boise City-Nampa, ID	4.6	11.90%	8.40%	2.90%
Provo-Orem, UT	4.1	8.90%	9.20%	2.90%
Seattle-Tacoma-Bellevue, WA	5.5	8.90%	10.00%	1.20%
Raleigh-Cary, NC	4	8.80%	11.40%	2.60%
San Jose-Sunnyvale-Santa Clara, CA	5.9	8.10%	12.40%	0.20%
Austin-Round Rock-San Marcos, TX	4.3	8.10%	8.70%	3.40%
Las Vegas-Paradise, NV	6	7.20%	7.90%	3.80%
San Francisco-Oakland-Fremont, CA	5.4	7.00%	11.50%	0.20%
Poughkeepsie-Newburgh-Middletown, NY	4.9	6.60%	7.70%	0.40%
Tucson, AZ	4.7	6.50%	6.30%	1.70%
Average for high growth metro areas	**4.9**	**8.20%**	**9.30%**	**1.90%**
Metro Areas with the lowest growth in patents from 1990 to 2010				
Lakeland-Winter Haven, FL	7.1	-1.10%	5.10%	1.10%
Pittsburgh, PA	5.6	-1.10%	10.10%	0.30%
Buffalo-Niagara Falls, NY	5.9	-1.20%	8.50%	-0.10%
Toledo, OH	6.8	-1.30%	6.10%	-0.20%
El Paso, TX	9.2	-1.40%	4.10%	1.40%
Dayton, OH	5.7	-1.60%	5.30%	-0.60%
Tulsa, OK	4.8	-1.70%	5.30%	1.10%
Chattanooga, TN-GA	5.1	-2.10%	6.90%	0.60%
New Orleans-Metairie-Kenner, LA	6.1	-2.50%	6.40%	-0.20%
Baton Rouge, LA	5.4	-5.30%	5.20%	1.60%
Average for low growth metro areas	**6.2**	**-1.90%**	**6.30%**	**0.50%**
Average for all large metro areas	**5.7**	**2.30%**	**7.90%**	**1.00%**

Source: Brookings analysis of Moody's Analytic, Bureau of Labor Statistics, Census Bureau Decennial Census, and Strumsky Patent Database. One patent is assigned to metro area if at least one inventor lives there.

Metro areas with the fastest growth in patenting tend to have lower unemployment during the period. Boise, Provo, Raleigh, Austin, Poughkeepsie, and Tucson all had high patenting growth and average unemployment rates below five percent; the average for the ten fastest growing metro areas was 4.9 percent. By contrast, large metros with slow patenting growth had an average unemployment rate of 6.2 percent. Places like Buffalo and Dayton represent once strong manufacturing hubs that lost their inventive momentum.

Patenting growth is also correlated with job growth, population growth, and increases in educational attainment rates. Yet, closer analysis reveals that education is more important to metro area job growth than patenting, which becomes insignificant. One explanation is that patenting growth only leads to job growth if it draws highly educated workers to the metropolitan area.

Overall, the evidence here is that patenting is good for metro area labor markets. The higher productivity does not seem to come at the expense of workers. Long-run unemployment rates are lower in metro areas with faster patent growth, meaning that opportunities for workers are more prevalent. Net job creation also tends to be higher in metros with higher patenting growth, but this effect is the result of growth in educational attainment.

Invention and the Creation of Public Companies

During the painfully slow recovery from the Great Recession, many have wondered whether America's entrepreneurial vigor has been sapped.[88] If patents are associated with the creation of new products and economic value, they may also help create new companies. That is, in fact, what the data suggest.

The effect of patenting on high-technology start-ups can be gleaned by examining the value of Initial Public Offerings (IPOs) occurring in metropolitan areas which have high patenting intensity. IPOs have come to be associated with high-technology start-ups, and are used by companies to raise money for expansion and monetize earlier investments.[89] A new database by innovation scholars has identified every tech-sector IPO from 1996 to 2006.[90] For this study, the IPO data were matched to metropolitan areas using the zip codes of the companies' headquarters. As many as 112 of 358 metropolitan areas were home to at least one company that went public between 2000 and 2006.

The figure below compares the average per capita value of IPOs, over the 2000 to 2006 period, for metropolitan areas with above and below average patents per capita over the preceding 1996–2000 period to allow time for patents to have an effect. Without inferring causality, those metropolitan areas with higher patent intensity witnessed IPO activity worth more than five times the per capita value. As the appendix discusses, the significant relationship remains after controlling for tech-sector employment shares, population, educational attainment, and output per worker.

Looking at either the value or number of IPOs across metropolitan areas, it is clear that patenting activity is highly correlated. Metro areas that patent more generate far more IPOs than those that do not. Table 8 sorts metros areas by those with the most value from IPOs from 2000 to 2006. Large patenting metros like San Jose, San Francisco, and Boston dominate the top five. Baltimore and Las Vegas are the only outliers in the top ten with few patents. Other metro areas with high patenting rates like San Diego, Seattle, and Austin also make the list.

Research universities, a scientifically-educated workforce, and collaboration play an important role in driving metropolitan innovation.

The evidence presented above is clear that patenting is strongly associated with national and regional economic performance. With so much at stake, it is worth analyzing why some metro areas patent so much more than others, and how others might boost invention. Four factors emerge as particularly

Figure 8. Average IPO Value per Capita for Metropolitan Areas with Above and Below Average Patents per Capita.

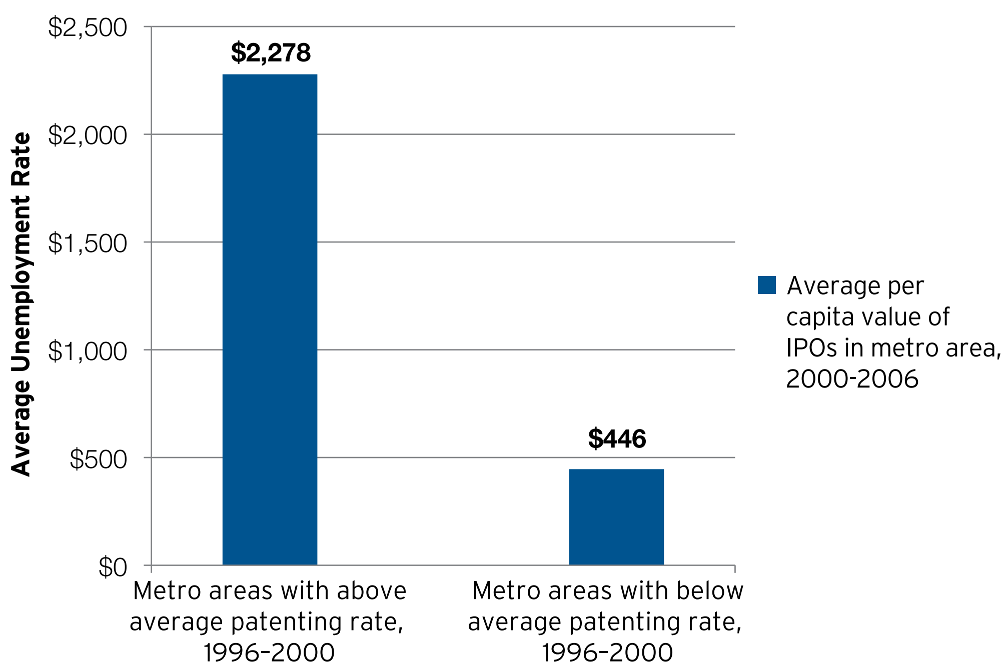


Table 8. Metro Areas with the Most Value from IPOs from 2000 to 2006 and the Number of Patents from 1996-2000

Metropolitan Area	Value of MSA IPOs, Mils	Number of IPOs	Largest IPO by value
San Jose-Sunnyvale-Santa Clara, CA	$84,264	89	Google Inc
New York-Northern New Jersey-Long Island, NY-NJ-PA	$64,074	72	Mastercard Inc
San Francisco-Oakland-Fremont, CA	$54,512	89	Webvan Group Inc*
Boston-Cambridge-Quincy, MA-NH	$30,676	54	Sycamore Networks Inc
Los Angeles-Long Beach-Santa Ana, CA	$27,135	42	Dreamworks Animation Inc
Washington-Arlington-Alexandria, DC-VA-MD-WV	$22,442	36	Kpmg Consulting Inc
Chicago-Joliet-Naperville, IL-IN-WI	$20,543	25	Cbot Holdings Inc
Baltimore-Towson, MD	$20,200	9	Corvis Corp
Las Vegas-Paradise, NV	$20,088	10	Las Vegas Sands Corp
San Diego-Carlsbad-San Marcos, CA	$19,570	36	Saic Inc
Dallas-Fort Worth-Arlington, TX	$16,450	21	Energy Transfer Equity Lp
Seattle-Tacoma-Bellevue, WA	$12,785	23	Onvia Com Inc
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	$12,521	22	Aramark Worldwide Corp
Houston-Sugar Land-Baytown, TX	$12,071	18	Complete Production Svcs Inc
Denver-Aurora-Broomfield, CO	$9,822	16	Regal Entertainment Group
Des Moines-West Des Moines, IA	$8,838	2	Principal Financial Group Inc
Minneapolis-St. Paul-Bloomington, MN-WI	$8,599	21	Lawson Software Inc
Atlanta-Sandy Springs-Marietta, GA	$8,125	17	United Parcel Service Inc
Bridgeport-Stamford-Norwalk, CT	$7,647	8	Priceline Com Inc
Austin-Round Rock-San Marcos, TX	$6,842	9	Silicon Laboratories Inc
Average for all metro areas	$23,360	31	

*Source: Brookings analysis of Strumsky patent database and IPO data from Martin Kenney and Donald Patton. 2010. Firm Database of Initial Public Offerings (IPOs) from June 1996 through 2006. (Version B). IPO data is reported in millions of 2011 dollars and refers to the 2000 to 2006 period. Patents refer to the 1996 to 2000 period. One patent is assigned to metro area if at least one inventor lives there. *This company turned out to be a rather high-profile failure, but such is the nature of innovation and entrepreneurship.*

strong predictors of patenting: tech-sector workforce, research universities, research collaboration, and college graduates with degrees in STEM fields, meaning science, computers, engineering, and mathematics related subjects.

Patenting is, of course, highly correlated with private-sector employment in patent-intensive industries. Three percent of the workforce is employed in the tech sector in the average metro area. From 2007 to 2011, 279 patents were invented in the average metro area with above average employment share in the tech sector, compared to just 20 in metros with below average employment. The fastest way to boost metro area patenting is to develop or attract large firms in high-patenting industries. The problem is that high-tech industries are defined as such, at least in part, because they patent more, and previous work has found that tax incentives and other fiscal inducements are much less important to more basic attributes like a skilled and flexible workforce, so the question is: What other factors can raise both patenting and high-tech employment?[91]

Access to university research institutions also seems to matter to both the rate of patenting and total level, and may also be important for firm attraction and development. A casual look at the data on which metros patent the most, brings to mind some of the nation's top research universities. San Jose has Stanford, Los Angeles has Cal Tech, San Francisco has Berkeley, Chicago has the University of Chicago, and Boston has MIT and Harvard. Yet, perhaps, large metro areas just happen to have major research universities, or industry success leads to funding for local research universities, as with Microsoft's support for the University of Washington.[92]

To examine this question in more detail, the analysis uses recent ranking from the National Research Council's (NRC) authoritative study on the quality of graduate research programs by institution across a large number of fields.[93] Programs were considered "top" ranked if they fell within the upper 90th percentile in their field, according to an average of the two most comprehensive summary rankings from the NRC, which give high weight to factors such as research grants won by faculty and quantitative GRE scores of students. The number of students was not considered in the present analysis.

The six metropolitan areas with the most patents all have at least 10 graduate level programs, and Detroit is the only metro in the top 10 on patenting that lacks access to top ranking science programs—since Ann Arbor, home of the University of Michigan, is not part of the Detroit metro area.

A more rigorous analysis reinforces the importance of institutions of science to patenting.[94] As Figure 7 shows, the 48 metro areas with at least one top-ranked science program patent at a higher rate than other metro areas. Yet, the data also show that second tier research programs also contribute to metro patenting. The 67 metro areas that do not have top-ranked science programs but do have lower ranked science programs still patent at a much higher rate than metros with no graduate programs in science. The results are similar for explaining the number of patents, rather than patents per capita. Surprisingly, the presence of national federal labs in a metropolitan area is not associated with more patenting, controlling for research programs, the tech sector employment share, science education attainment rates, and population size.[95]

Strong research universities seem to enhance metro areas invention beyond the mere presence of a tech sector. The positive and significant association between science programs and patenting remains after controlling for population and the share of employment in the tech sector, whether predicting the level of patents or the patenting rate (see Appendix Table 4 for details). The relationship between top science programs and patenting remains significance even if Boston, San Jose, and San Francisco are excluded. This analysis cannot rule out the possibility that universities become better as a result of corporate support from the tech sector.

Ranked by the presence of top science programs, the Boston metropolitan area dominates all others with 43 top science programs, thanks to Harvard and MIT. Yet, as Table 9 implies, California is the strongest state. It has 3 of the top 5 metro areas and 6 in the top 20, led by UC-Berkeley, Stanford,

Figure 9. Metro Patenting and Presence of University Graduate Programs in Science

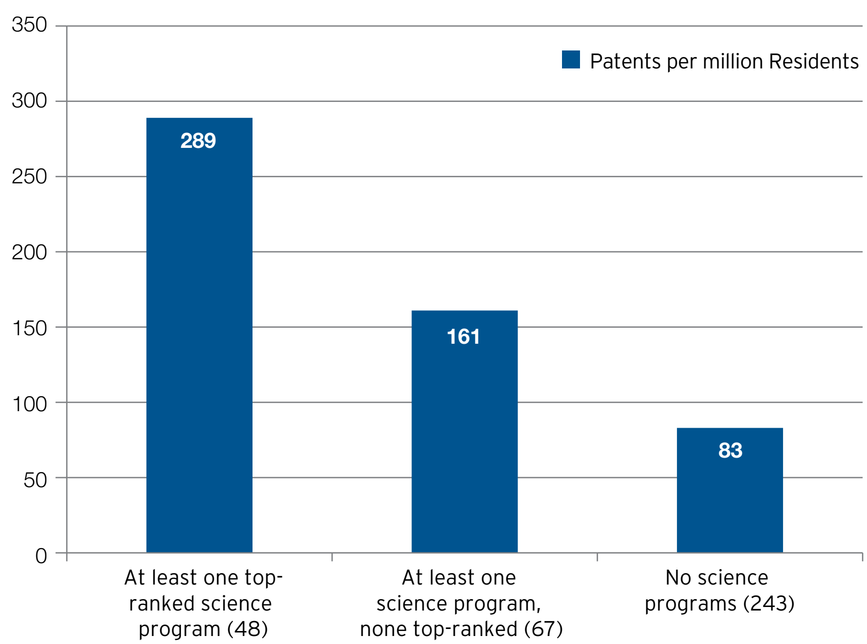


Table 9. Metro Areas with Top-Ranked Research Programs in Science Fields and Recent Patenting Rate

	Number of top-ranked science programs	Patents per million residents, 2007–2011	Institution with Most Top Programs
Boston-Cambridge-Quincy, MA-NH	43	874	Harvard University
San Francisco-Oakland-Fremont, CA	33	1,630	University of California-Berkeley
Los Angeles-Long Beach-Santa Ana, CA	30	423	California Institute of Technology
San Jose-Sunnyvale-Santa Clara, CA	24	5,035	Stanford University
New Haven-Milford, CT	15	590	Yale University
Trenton-Ewing, NJ	13	1,072	Princeton University
Ann Arbor, MI	12	1,690	University of Michigan-Ann Arbor
Durham-Chapel Hill, NC	11	838	University of North Carolina, Chapel Hill
Madison, WI	11	1,112	University of Wisconsin-Madison
Chicago-Joliet-Naperville, IL-IN-WI	10	408	University of Chicago
New York-Northern New Jersey-Long Island, NY-NJ-PA	10	365	Columbia University
Champaign-Urbana, IL	9	414	University of Illinois at Urbana-Champaign
State College, PA	9	597	Penn State University
San Diego-Carlsbad-San Marcos, CA	8	1,035	University of California-San Diego
Seattle-Tacoma-Bellevue, WA	8	1,165	University of Washington
Ithaca, NY	7	401	Cornell University
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	7	959	University of Pennsylvania
Santa Barbara-Santa Maria-Goleta, CA	7	652	University of California-Santa Barbara
Atlanta-Sandy Springs-Marietta, GA	6	283	Georgia Institute of Technology
Sacramento--Arden-Arcade--Roseville, CA	6	184	University of California-Davis

Source: Brookings analysis of National Research Council data on academic programs, Strumsky Patent Database, and Census Bureau. One patent is assigned to metro area if at least one inventor lives there.

and Cal-Tech and UCLA. Some of California's lesser known schools also contribute to the high ranking of San Diego, Santa Barbara, and Sacramento. Seattle makes the top 20 with the University of Washington. New York, Philadelphia, and other metros with Ivy League institutions make the list, including Trenton, New Haven, and Ithaca. The South is under-represented but includes the well-known Durham-Chapel Hill area, and Atlanta, with Georgia Tech. Four Big 10 schools anchor strong metro performance in Champaign-Urbana, State College, Ann Arbor, and Madison.

The uneven presence of top research universities helps explain the uneven distribution of patenting across metro areas. The 48 metro areas with high-ranking science doctoral programs account for the majority—62 percent—of all patents invented in metro areas from 2007 to 2011, though they have just 46 percent of the total metropolitan population, as of 2010. Another 25 percent of metro area patents are invented by researchers living in an area with at least one science program, though none in the top tier. Just 14 percent are invented by researchers living in metro areas with zero doctoral programs in science, though these areas are home to 27 percent of the total metropolitan population.

While research universities also produce STEM graduates, a metropolitan area's STEM bachelor's degree attainment rate also appears to have an independent effect on invention. A highly STEM educated workforce benefits existing tech firms and helps attract new ones. The average metropolitan area has a STEM degree attainment rate of just 8.5 percent, though it is above 20 percent in the metro areas of Ithaca, New York, Boulder, Colorado, Corvallis, Oregon, San Jose, Ames, Iowa, Ann Arbor Michigan, and Washington D.C. Just a five percentage point increase in the share of workers with a STEM bachelor's degree predicts an increase of 176 patents per million residents.

Another factor associated with high-patenting rates is the degree of collaboration. Metropolitan areas with more inventors per patent—a measure of research team size—patent at higher rates. In the average metropolitan areas, patents typically have three co-inventors. Increasing the average number of collaborators by one, predicts 87 extra patents per million residents, controlling for other variables.

Large metro areas like San Francisco, Cincinnati, Seattle, Albany, and San Diego recognize at least four inventors on the average patent granted from 2007 to 2011. A few smaller metro areas also have high collaboration rates and high innovation, rates like Poughkeepsie-Newburgh-Middletown, New York, Boulder, Colorado, Trenton, New Jersey (because Princeton is included). There are also a disproportionate number of high-collaboration metro areas in the Midwest, especially Wisconsin: Oshkosh-Neenah, Appleton, Racine, and Madison.

One reason why metro area team size varies is related to industry differences. The patent categories—like industries—with the largest average team sizes include chemistry technology, biotechnology, data processing, video distribution, computer software, nanotechnology, computer hardware, and resins. These more collaborative subcategories of patents are more likely to involve universities and the public sector. There is a very high correlation between the average team size of a patenting category and the share of patents owned by universities or funded by federal dollars. Another factor may be state "non-compete" regulations that sometimes prevent workers from putting their skills to work for competitors.[96]

Some readers may wonder if the results discussed above—particularly metropolitan changes in patenting—are driven by industry-patent orientations of metropolitan areas, rather than the underlying assets mentioned. In other words: Did San Jose become so innovative because it was lucky enough to be strong in technological classes that proved to be fast-growing over recent decades?

To test this idea, the change in the number of patents was calculated for each USPTO class from 1980 to 2010 (using 5-year moving averages in grant year to adjust for year-to-year anomalies). Semiconductor device manufacturing processes expanded the most. For that class, 4,772 more patents were granted in the 2010 period than the 1980 period. Various IT and communications technology patents were also at the top, though a few bio-tech classes were as well. The question is this: Did the expansion of these technologies nationally and globally account for the increase in metropolitan patenting for those places that already had a large share of these patents in 1980?

Not entirely. Metropolitan San Jose did have a large market share of the semiconductor processes patents in 1980 (roughly 7.6 percent of all grants came from inventors living there), but New York City had an even larger share, at 9.7. Yet, by 2010, New York's city's market share fell to 3.2 percent while San Jose's increased to 10.1 percent. Looking across all patent classes, it turns out that only 36 percent of San Jose's 2010 patents could be explained by the rise of patent classes, based on its 1980 market share. New York, on the other hand, had fewer patents in 2010 than expected, based on its 1980 market share.

To be more systematic, a regression analysis was performed to examine 1980 to 2010 changes in patenting while controlling for the patent class effect.[97] It turns out that the patent class effect is strongly significant, but so are the other variables mentioned, including the number of top science research programs (which had the highest statistical significance), tech sector employment shares, population, and bachelor's degree attainment (science bachelor's degree attainment was not available in 1980). In other words, the places that garnered extra market share in large patent classes—and therefore most took advantage of market trends—often had leading academic research programs in science fields and a large highly skilled workforce.

Patents funded by the U.S. government tend to be of especially high quality, and federal small business R&D funding is associated with significantly higher metropolitan productivity growth.

R&D is extremely important to innovation. To illustrate, consider that 66 percent of R&D-performing companies introduced a new or significantly improved product into the market between 2006 and 2008, compared to only 7 percent for companies that do not perform R&D.[98] Likewise, R&D performing companies are much more likely to rate patents as somewhat or very important to the company (41 percent) compared to non-R&D performing companies (3 percent).[99]

From the 1950s through the 1970s, most R&D funding in the United States was provided by the federal government. In the late 1970s, the share fell below half and now stood at slightly less than one third in 2009.[100] The primary rationale for public investment in R&D is that the resulting knowledge and innovations are partly public goods, meanings that the companies that discover new ideas or invent new technologies gain only a fraction of the social value. There is strong empirical evidence behind this theory, and economists estimate that levels of R&D are roughly one quarter of what they should be to optimize growth.[101] Moreover, the recent history of technology shows that the public sector has funded key developments across a wide range of important technologies, such as the internet, satellite communications, health treatments, and even hydraulic fracturing for natural gas (or fracking).[102]

Despite the massive public sector role in funding R&D, only a small portion of the funding—8 percent in 2009—is performed directly by government agency employees. Most of the money—over 60 percent in 2009—goes to private companies, but a substantial and growing share—about a third—goes to academia and federal research labs. In fact, roughly two-thirds of academic R&D has come from the public sector in recent years, with most from the federal government and a smaller portion from state and local sources. Along these lines, federal R&D is more likely to be used for basic research. In 2009, federal dollars made up 53 percent of basic research funding, but only 31 percent of total funding.[103] These facts explain why corporate R&D funding is much more likely to yield a patent than government research dollars. Since 2000, only 2 percent of patents have declared federal government funding in an average year, which is down only slightly from the 1980s.

Overall, in 2011, 91 percent of granted patents were invented by private corporations, 1 percent by individuals, 1 percent by the federal government, 2 percent by national labs, and 6 percent by universities (up from 1 percent in the 1970s). That same year, 4 percent of all patents reported funding from the federal government.

While the direct federal government role is small, federally financed patents of are of higher quality than those funded by industry. Government funded patents receive significantly more citations and claims, regardless of the patent owner, than other patents. Table 10 presents the data on claims. Universities stand out as having the largest number of claims per patent, a sign of broader intellectual property claims. However, this is partly because university researchers are more likely to receive government financing. Patents invented by workers at private companies contain 4.4 more claims per patent if sponsored by government funding, compared to those with no government funding. Individual researchers and national labs also invent patents with more claims if funded by the government.

The results are similar looking at patent citations within 8 years. Table 11 reports the results. Universities, again, are producing patents with the highest rate of citations, followed by private companies. Patents that receive public funding garner significantly more citations per patent, regardless of the affiliation of the inventors

Not all federal funding yields patents of the same quality, according to these measures. Funding from the Defense Department's Advanced Research Projects Agency (DARPA) garner the highest value patents, measured by claims per patent. DARPA sponsored patents are also cited much more frequently than private sector patents, with 8.8 citations per patent over an 8 year period. The National Science Foundation is second on claims but receives the highest number of citations per patent, at 9.1. The Department of Energy and EPA are roughly in the middle on claims, and score somewhat poorly on citations, compared to other programs. NASA does better on citations than claims. Overall, however, government funded patents from any source score at a higher rate of value than the average private company owned patent.

Other than government funding, patents with higher claims tend to have more collaborators. This

Table 10. Average Claims per Granted Patent by Assignee and Government Funding, 1975–2012 Applications

	Claims in average patent	Claims in average patent with government funding	Claims in average patent without government funding
Private Company	14.4	18.8	14.4
Individual	12.5	22.2	12.5
University	18.4	19.4	17.9
Government Agency	11.6	10.5	12.3
National Lab	14.9	18.4	14.2

Differences between those that receive and do not receive government funding are statistically significant, with p-values less than 0.00 and t-statistics above 10.

Table 11. Citations Within Eight Years per Granted Patent by Assignee and Government Funding, 1975–2012 Applications

	Citations of average patent	Citations of average patent with government funding	Citations of average patent without government funding
Private Company	6.9	8.3	6.9
Individual	5.7	9.9	5.7
University	8.0	8.6	7.7
Government Agency	4.9	5.0	4.8
National Lab	4.8	7.2	4.3

Differences between those that receive and do not receive government funding are statistically significant, with p-values less than 0.00 and t-statistics above 2.8.

is evident at the metropolitan scale, as Table 13 shows. The metropolitan areas with the most claims per patent—San Jose, Houston, San Diego, Washington D.C., and Albany—tend to have a high number of inventors per patent, and to a higher share of patents funded by the federal government. The ten metropolitan areas with the most claims per patent had average team sizes of 3.6, compared to 2.6 for those with the fewest claims per patent (e.g. McAllen, Cape Coral, Youngstown, and Bakersfield). Likewise, the share receiving federal funding is 3.1 percent for the top 10, compared to just 0.8 percent for the bottom 10. In Albuquerque, home to Sandia Laboratory and Air Force research labs, the federal share is particular high.

The foregoing data suggest that patents funded with federal R&D dollars tend to be more socially valuable than those funded with private dollars, but they do not shed light on whether or not a dollar of public investment yields a higher social return than a dollar of private investment. As mentioned, federal R&D spending tends to target more basic projects which are less likely to yield patents and commercial products. Yet, there is one large federal program that focuses on applied research and commercial development: the multi-agency Small Business Research program (SBIR).

This program, which gives out roughly $2 billion per year, lends itself more easily to a comparison with private sector efforts and has been well-studied. Projects that make it to a second phase of funding yields an average of 1.7 research publications and 0.6 patents for every grant, according to a comprehensive study.[104] With an average grant size of $656,000, this amounts to just over $1.1 million per patent and $0.4 million per scientific publication. By this standard, the program is actually more efficient than the private sector at creating patents, given that in recent years one patent has been granted to domestic inventors for every $3.4 million of total U.S. R&D spending. The SBIR average grantee earns more than twice as much in sales and licensing of technology than it receives in federal

Table 12. Claims and Citations per Patent by Government Agency Funding, 1975–2012 Applications

	Claims per patent	Citations within 8 years per patent
DARPA	22.0	8.8
NSF	21.9	9.1
ARMY	19.9	8.1
EPA	19.7	6.4
AIR FORCE	18.6	8.7
DOE	17.6	7.3
NIH	17.4	6.6
NASA	17.3	8.7
NAVY	16.5	7.8
Other Federal Funding	14.5	8.6

Table 13. Large Metropolitan Areas with the Most Claims per Patent, 2007-2011

	Claims per patent, 2007-2011	Inventors per patent, 2007-2011	Share of patents federally funded
Large metropolitan areas with most claims per patent			
Honolulu, HI	19.8	2.4	2.4%
San Jose-Sunnyvale-Santa Clara, CA	18.2	4.0	0.5%
Houston-Sugar Land-Baytown, TX	17.5	4.0	1.3%
Boise City-Nampa, ID	17.2	2.7	0.0%
Albuquerque, NM	16.9	3.3	17.7%
San Diego-Carlsbad-San Marcos, CA	16.4	4.3	2.3%
Washington-Arlington-Alexandria, DC-VA-MD-WV	16.2	3.6	2.2%
Buffalo-Niagara Falls, NY	16.1	4.0	1.5%
Tucson, AZ	16.1	3.8	1.4%
Albany-Schenectady-Troy, NY	15.8	4.4	1.7%
Average of top 10 MSAs	17.0	3.6	3.1%
Large metropolitan areas with fewest claims per patent			
Chattanooga, TN-GA	9.7	2.4	0.0%
Bakersfield-Delano, CA	9.4	2.4	0.5%
Little Rock-North Little Rock-Conway, AR	9.3	2.8	2.0%
Nashville-Davidson--Murfreesboro--Franklin, TN	9.3	3.5	2.3%
Miami-Fort Lauderdale-Pompano Beach, FL	8.5	2.6	0.6%
Modesto, CA	7.9	2.5	1.0%
Lakeland-Winter Haven, FL	7.7	3.4	0.2%
Youngstown-Warren-Boardman, OH-PA	7.5	2.7	0.0%
Cape Coral-Fort Myers, FL	6.3	1.4	0.0%
McAllen-Edinburg-Mission, TX	5.6	1.5	1.3%
Average of bottom 10 MSAs	8.1	2.5	0.8%
Average of all large MSAs	12.8	3.5	1.5%

Source: Brookings analysis of Strumsky Patent Database

funding, even as it attracts extra private sector funding. In all, SBIR seem to add roughly three times as much to the economy as it costs taxpayers in direct private economic benefits.[105]

Aside from patents, future sales, and the stimulation of investment, federal research dollars that support basic science and academic work have another hugely important effect on innovation through their fostering of scientific knowledge. In one recent survey of U.S. inventors who had filed patents in the United States, Japan, and Europe, 39 percent said that scientific and technical literature was an important or very important source of knowledge suggesting the research that led to their patent.[106] According to NSF data, just over 10 percent of U.S. patents actually cite academic publications.[107] Of course, there are many other potential technological (not to mention social) benefits to academic knowledge that never get translated into patents because they affect things that are hard to patent like theories, diagnoses, methods, and techniques.

With this in mind, the SBIR program's success at contributing to the scientific literature makes it look even more attractive. By contrast, researchers at corporations almost never publish in scientific journals, mostly because the valuable knowledge could immediately be adopted by competitors. Beyond SBIR, the federal role is quite large in fields like medicine and biotech. According to the database PubMed, there were over 100,286 journal articles funded with NIH money published in 2011 alone, which was the culmination of a rapid but steady increase in recent decades. To put that number in perspective, there were only about 800,000 English-language PubMed articles published in 2011 from any country, many of which received funding from non-U.S. governments.

Thus, it should be no surprise that metropolitan areas that receive more SBIR awards experience

Table 14. Metropolitan Areas with the Highest Number of Annual SBIR Awards, 2007-2011

	SBIR Awards	Millions of dollars in grant money per year
Boston-Cambridge-Quincy, MA-NH	676	$237
Los Angeles-Long Beach-Santa Ana, CA	424	$134
Washington-Arlington-Alexandria, DC-VA-MD-WV	378	$124
New York-Northern New Jersey-Long Island, NY-NJ-PA	221	$88
San Diego-Carlsbad-San Marcos, CA	192	$74
San Francisco-Oakland-Fremont, CA	181	$66
San Jose-Sunnyvale-Santa Clara, CA	161	$53
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	144	$54
Boulder, CO	122	$38
Huntsville, AL	101	$31
Chicago-Joliet-Naperville, IL-IN-WI	99	$31
Denver-Aurora-Broomfield, CO	98	$32
Dayton, OH	95	$27
Austin-Round Rock-San Marcos, TX	93	$30
Ann Arbor, MI	92	$36
Seattle-Tacoma-Bellevue, WA	91	$38
Baltimore-Towson, MD	81	$27
Minneapolis-St. Paul-Bloomington, MN-WI	71	$25
Atlanta-Sandy Springs-Marietta, GA	67	$22
Tucson, AZ	66	$20
Average for all metropolitan areas	16	$19

Source: Brookings analysis of SBIR program

higher productivity growth, even accounting for patents, tech-sector employment, population, education, and industry concentration, as was done earlier. The details of the analysis are shown in Appendix Table 5, and the main idea is that the amount of SBIR funding or the number of awards going to a metropolitan area in one year predicts faster productivity growth over the following ten years.

The 20 metropolitan areas that won the most SBIR awards from 2007 to 2011 are listed in Table 14. Large metro areas like Boston, Los Angeles, Washington, New York, and San Diego top the list. On a per worker basis, a different group of university-centered or lab-centered metropolitan areas are at the top, including Blacksburg, Virginia (Virginia Tech, Boulder, Colorado (the University of Colorado), Ithaca, New York (Cornell), Huntsville, Alabama—which has three Department of Defense labs—and Ann Arbor, Michigan.

The size of the SBIR effect is statistically and economically meaningful. The average grant in 2011 was just under half a million dollars, while the average effect on productivity was large enough to add roughly $3.3 million dollars to the regional economy. That represents a nearly seven fold return on investment on tax dollars, just for that region. The national and international benefits of the research are likely to be non-trivial as well. As with other aspects of the analysis in this report, these results could be biased by omitted variables or reverse causality, and so the precise causal effect remains unknown. Yet, the results here are consistent with other micro-level studies that avoid such problems.

Discussion and Policy Relevance

This report documents how a strong national innovation system plays out across a dispersed array of U.S. metropolitan areas, contributing to economic growth in both local places and across a large and diverse country.

Clear in these pages is the continued vibrancy of the U.S. innovation as well as the general utility of the nation's patenting system. Clear too is the centrality of geography to those systems, which depend on the intense matching, learning, and sharing that constantly goes on among people, institutions, and resources in urban regions. Along these lines, the paper at once affirms the general effectiveness of the U.S. invention system on most (though not all) fronts and documents that large metros constitute the critical sites of American innovative activity.

Above all, the report affirms the economic importance of invention and the continued dynamism of the U.S. invention system, even as the global economy becomes increasingly more competitive.

But the assessment should not license complacency. Just as these pages make clear the centrality of innovation to prosperity they underscore the increasing pace and competitiveness of invention. Patent ownership is more dispersed now than in previous decades going back to 1975, if not earlier; foreign inventors have never owned such a large share of USPTO patents, and given the elevated participation of developing countries, the global rate of invention has probably never been higher. This is born out in international comparisons: While still dominant in absolute numbers, the United States is ranked ninth on patents per capita, and just 13th on scientific research articles per capita.[108] Such trends argue that private firms, large and small, need to double down on their investments in R&D, invest in increasingly collaborative R&D models, and "ring-fence" those activities from the short-term pressures of Wall Street and quarterly reporting.

At other points, meanwhile, the paper makes clear the critical role that public policy plays in stoking, organizing, and accelerating innovative activity. In doing so, the report raises a number of questions about the nation's support of its universities, trends in R&D funding, the adequacy of U.S. education and training, and the integrity of the patent system. Likewise, the extreme variation of metros' inventive activity as measured by patenting rates underscores the fact that in many places the available mixes of people, resources, institutions, and industries in the United States remain massively sub-optimal.

And so the present analysis—which reports on the workings of a national innovation and patenting system that is at the same time intensely local—points to the need for a two-tiered, federalist approach to maintaining and maximizing the vitality of the U.S. system. Similarly, two general areas of effort come to the fore:

- The federal government should establish and maintain a sound platform for innovative activity
- Regions and their states must work foster innovative activity "bottom up"

On both fronts, it should be noted, the particular array of policy initiatives that will be relevant will vary sharply with the extreme variation of the conditions that exist in U.S. metropolitan areas, where innovation metros like Boston, San Jose, and San Francisco race to maintain their world-leading edge even as metros like McAllen and Modesto—with no research universities, meager levels of human capital in STEM fields, and few technology forms—struggle to assemble the least purchase in the innovation game. No one policy or approach will suffice across such a diverse set of local innovation systems.

Federal platform-setting

The federal role in promoting innovation is foundational. All jurisdictions—national, state, and local—have an interest in maximizing innovation. After all, the material well-being of all places now hinges on the continuous creation of new ideas, new technologies, and new products—and must be maximized. However, the federal government—like all other national governments in the world—will always have a special role in fostering innovation given the presence of pervasive, far-reaching market failures including externalities, network failures, system interdependencies, and the public-goods and border-crossing nature of technology platforms.[109] These broad-ranging complications of innovative activity always and everywhere threaten to depress the level of the innovation. Accordingly, the federal government retains a crucial role in responding to those problems and in doing so setting a stable and adequate platform for innovative activity in the nation's industries and metropolitan regions.

The evidence that federal R&D spending is worthy of public support is abundant. In addition to the findings introduced above, economists have carefully studied R&D programs like SBIR.[110] In the 1990s, the SBIR portfolio was roughly equal in size to the private sector venture capital market, and at various points in the program's history, firms like Apple, Compaq, Intel, and Federal Express received grants.[111] Including the Small Business Technology Transfer Program (STTR), from 1997 to 2011, $26 billion was given out to fund nearly 100,000 projects.[112] Studies have shown that grantees from these programs attracted subsequent private sector investments and tend to outperform their peers on economic performance measures.[113]

Along those lines, it has become increasingly clear that the nation—to maintain its leadership in the inventiveness that drives economic growth—must consistently work on at least three fronts to: invest in the maintenance of a robust U.S. research enterprise; help ensure the existence of an adequate supply of skilled workers; and safeguard the integrity of the patent system.

A first priority of federal platform-setting must be to **invest in a robust research enterprise** in the United States. Copious amounts of basic and applied research remain a critical foundation for innovation, invention, and prosperity. Or as pronounced the landmark 2005 . National Academy of Science report *Rising Above the Gathering Storm,* "A balanced research portfolio in all fields of science and engineering research is critical to U.S. prosperity."[114] Which is why the federal government—recognizing the public good nature of research—has traditionally supported both basic and applied scientific and engineering research, both through grants to universities and via subsidies to companies and private inventors.

And yet, in recent decades the federal commitment to funding such activities has seemed to waver. Overall federal R&D investments grew in constant dollars by just 2.1 percent per year each year from 1980 to 2009—lower than the rate of GDP growth over that period (2.7 percent) and lower than federal R&D spending growth between 1953 and 1980 (5.4 percent). Looking more specifically at academic and corporate accounts the story persists. The rate of growth in federal spending on academic R&D has gradually declined from the 1970s through the 1990s. If not for the 2009 American Recovery and Reinvestment Act (ARRA or the Recovery Act), the 2000s would have represented the slowest decade of federal academic R&D spending since data have been reported. ARRA gave a 19 percent boost in federal academic R&D spending over congressional obligations. The problem is that ARRA programs are temporary so without legislative action, federal R&D spending growth will dip substantially, potentially depressing economic growth in future decades. Given the enormous importance of academic research to innovation, it is essential to maintain its growth.[115]

At the same time, support of the nation's most important incentive for private-sector R&D activity—the Research and Experimentation (R&E) Tax Credit (usually called the "R&D tax credit)—has also dwindled. Established in 1981, the credit was the world's first and provided companies large and small with a powerful added incentive for R&D investment given the fact firms often cannot fully capture the returns on their investments due to spillover effects.[116] However, over time, the credit has become less generous and predictable relative to what other countries provide. As a result, the Information Technology and Innovation Foundation (ITIF) recently concluded that the United States now ranks 27th in the world in terms of R&D tax incentive generosity.[117] At the same time, uncertainty about the availability and level of the U.S. credit due to repeated expirations and reauthorizations may well have undercut long-term planning and overall R&D investments.

And so the federal agenda for maintaining and increasing the robustness of the U.S. research enterprise must include new investments in the adequacy, stability, and effectiveness of the nation's research platform. To start with, the nation must reassert its world leadership on research investment by supporting with appropriations, even in the context of deficit reduction, President Obama's goal that total U.S. R&D expenditures reach and sustain a level of 3 percent of GDP—which is just above the historic high of 2.9 percent, achieved in 1964.[118] At the same time, Congress needs to strengthen the R&E Tax Credit and make it permanent.[119] An increase of the rate of the Alternative Simplified

Table 15. Annual Growth Rate in Federal Obligations for Academic R&D by Decade

Decade	Annual Growth Rate
1970-1979	4.3%
1980-1989	3.8%
1990-1999	3.5%
2000-2009, without ARRA	2.7%
2000-2009, with ARRA	4.7%

Source: Brookings analysis of National Science Foundation data

Credit from its most recent level of 14 percent to 20 percent—combined with simplifications to ease the credit's use—would go a long way toward re-stimulating private-sector innovative activity as the nation's economy recovers from the Great Recession.

Finally, in bolstering the robustness of the U.S. research enterprise the federal government should maintain and step up its recent experiments with the creation of new formats and institutions for the acceleration of innovative activity. In this respect, with the innovation game increasingly complex, collaborative, and fast-moving getting the scale of the needed investment levels right is only part of the need. Implementing more and better models for inciting more effective translational, collaborative, and purpose-driven research matters just as much.[120] All of which argues for the nation to *step up federal support of promising new collaborative innovation models* including: various "grand challenge" research institutes (such as the Department of Energy's Energy Innovation Hubs or the proposed National Network of Manufacturing Innovation); proof-of-concept centers and new region-based translational platforms like the Department of Commerce's i6 Green and Jobs and Innovation Accelerator challenges; the government's several regional innovation cluster programs; and various longer-standing programs like the NSF's Engineering Research Centers and Industry/University Cooperative Research Center Program and the National Institute of Standards and Technology (NIST)'s Technology Innovation Program and Manufacturing Extension Partnership.[121] The creation and sustained support of more of these focused, multi-disciplinary, and collaborative technology development platforms will be crucial to ensuring that the nation extracts the most usable innovation out of its investments by inciting research that transcends stovepipes and sectoral divides, links academia to industry, and works on compelling problems. Making sure that these mechanisms take on a strong regional flavor and encourage "bottom up" activity will maximize the value of these efforts.

Equally important to securing a competitive platform for the next era of U.S. innovative activity is the imperative to **ensure the existence of an abundant supply of skilled workers**. Quite simply, the strength of the U.S. innovation system absolutely depends on the skills and ideas of the nation's workforce. Highly trained scientists or technicians are essential to conduct the research and implement the technologies needed to drive innovative companies and perform product and process development. Likewise, education is closely linked to entrepreneurship. According to one recent survey, 94 percent of U.S. patent inventors—with inventions between 2000 and 2003—hold a university degree, including 45 percent with a PhD. Of those, 95 percent of their highest degrees were in STEM fields, including over half in engineering.[122] Given this, it has been critical that for generations the United States constantly amassed the world's strongest cadre of highly-skilled scientists, engineers, and technology workers, both by educating and motivating top students here in the United States and by attracting the best and brightest from abroad.[123]

And yet, there is a problem: Notwithstanding the nation's history of educational achievement, U.S. educational attainment—especially in critical science, technology, engineering, and mathematics (STEM) domains—now lags that of many other nations. Only a small slice of the U.S. population is academically prepared to engage in the innovative scientific or technical research that leads to patents. Out of 34 developed countries, the United States ranks just 24th STEM graduates with a Bachelor's degree (equivalent) or higher as a share of the population aged 20 to 24 (see Table 16). Only 28 percent of U.S. degrees are being issued in STEM fields, compared to over 50 percent in many developed countries. At the heart of the challenge for the United States is the immense gap in outcomes between U.S. institutions of higher learning and its primary and secondary schools. Fifteen year-old students in the United States score lower on science and math exams than 23 other developed countries. At the other end, according to the Leiden Ranking (from Leiden University in the Netherlands), all ten of the top universities in the world are in the United States and 43 of the top 50.[124] Yet, at the elementary and secondary level international comparisons of U.S. students' on science and mathematics consistently place the United States much further down—as low as 23rd among OECD countries.[125] In addition, large interest-level and achievement gaps that exist among multiple groups, with African Americans, Hispanics, Native Americans, and women seriously underrepresented in many STEM fields. At the same time, admission slots to top universities are increasingly taken up by children from affluent families, as the locally controlled K-12 system increasingly allocates quality education to children based on their parent's ability to afford high housing costs.[126] Meanwhile, President's Council of Advisors on Science and Technology (PCAST) recently projected the need for producing, over the next decade, approximately 1

Table 16. Science Education Statistics for 2009, by Country

	STEM Tertiary Degree Graduates as Share of Population aged 20-24	Share of Tertiary Graduates in STEM Fields	Ranking of Universities by Average Quality of Institutions	Ranking of 15-year old student Test Scores on Math and Science
Finland	9%	58%	16	1
Korea	7%	59%	27	2
Slovak Republic	7%	37%	-	25
Czech Republic	6%	43%	33	20
United Kingdom	6%	41%	5	13
Poland	6%	27%	34	14
Portugal	6%	44%	21	26
Ireland	5%	37%	8	18
New Zealand	5%	37%	18	5
Iceland	5%	29%	-	16
Australia	5%	31%	13	8
France	5%	47%	15	19
Germany	5%	55%	14	10
Denmark	5%	32%	3	15
Sweden	4%	48%	7	24
Switzerland	4%	40%	1	6
Austria	4%	49%	12	22
Canada	4%	41%	11	4
Spain	4%	42%	22	28
Israel	4%	36%	17	31
Norway	4%	29%	10	17
Greece	3%	50%	24	30
Belgium	3%	37%	9	11
United States	3%	28%	4	23
Netherlands	3%	24%	2	7
Slovenia	3%	34%	31	12
Hungary	3%	31%	30	21
Estonia	3%	41%	-	9
Italy	3%	38%	20	29
Japan	2%	24%	28	3
Mexico	2%	50%	38	34
Turkey	2%	28%	35	32
Chile	1%	25%	32	33
Luxembourg	1%	53%	-	27

Source: Educational attainment based on Brookings analysis of OECD other data; Data are for 2009; University rankings calculated from Centre for Science and Technology Studies, Leiden University, The Netherlands and based on average number of citations of academic publications in science fields. 15 year old test scores are based on average of Program for International Student Assessment (PISA) scores for math and science; rankings are only among the countries listed.

million more college graduates in STEM fields than is expected under current assumptions.[127] The bottom line: The United States needs to provide more egalitarian educational opportunities in order to create a larger and better-trained technological workforce; otherwise its innovation system will crumble.

It is absolutely critical, then, that the United States move to increase the supply and quality of the U.S. STEM workforce. So what is the federal role in bolstering the nation's STEM workforce? PCAST confirms the need for the nation to redouble its effort on three fronts: K-12 STEM education, university STEM education, and recruitment of highly-skilled foreign workers.

The project should begin with efforts to *improve K-12 math and science education.* This task is a prerequisite for renewing the U.S. innovation system and improving the distribution of its economic gains and it will be gargantuan. Fortunately, however, numerous reports by PCAST and other authorities detail significant consensus about the sort of action steps required.[128] At the broadest level, most observers suggest the federal government should vigorously support the current state-led effort to develop common standards in STEM subjects and invest in programs designed to produce specifically trained middle- and high-school STEM teachers and recognize the best of them as STEM master teachers. Likewise, many analysts underscore the need to inspire students' interest in STEM subjects through individual and group experiences outside the classroom and through more immersive, in-depth, courses oriented to more active learning. To that end PCAST and others call for the federal government help fund new federal, state, or local programs to provide high-quality after- and outside-school or extended day STEM experiences (such as STEM contests, fabrication laboratories, company visits, summer and afterschool programs, and so on). Finally, numerous experts call for the federal government to actively promote the establishment of hundreds of new STEM-focused schools. PCAST calls for the federal government to help create at least 200 highly-STEM-focused high schools and 800 STEM elementary and middle schools while ITIF calls for Congress to fund the Department of Education to create 400 new specialty STEM high schools.

Once students are inspired and prepared, meanwhile, they must be engaged to excel. For that reason, work to *improve undergraduate STEM education,* especially during the first two years of college, will also be crucial to bolstering the nation's STEM workforce. This engagement process must begin with a continued commitment to maintaining Pell Grants and other federal supports for higher education since improving STEM education at the K-12 level and moving more young people into the STEM pipeline will be futile if college is unaffordable or out-of-reach. But beyond that, new efforts must be launched to entice more undergrads into STEM courses and then into STEM majors in their first two years of higher education. Washington has a role to play at this by helping to catalyze and finance the development, dissemination, and wide adoption of empirically validated college STEM teaching practices, including the replacement of standard laboratory course with more discovery-based research courses.[129]

Yet even positing outstanding progress in the next decade of producing a more robust cadre of home-grown researchers, technologists, and technical workers the nation will continue to need to *attract and retain significant numbers of the world's best researchers and students from abroad.*[130] Immigrants have long played a crucial role in the U.S. innovation system. Such foreign-born citizens and visitors represent fully 24 percent of the nation's scientists and 47 percent of U.S. engineers with doctorate degrees. Moreover, their numbers encompass one-quarter of the founders of U.S. public companies that were venture capital-backed.[131] And so the United States must continue to draw the best science and engineering talent from foreign countries even as more nations compete to attract such students and workers and as more of them elect to seek opportunity at home. One possible strategy: Expand the number of high-skilled foreign workers that may be employed by U.S. companies as one element of a comprehensive immigration reform. Two mechanisms for this would be to: Allow foreign students that receive a graduate STEM degree from a U.S. university to receive a green card (which would also cover his or her spouse and children) and to increase the number of H-1B visas. Such provisions will not only add to the nation's stock of talent but ensure that the nation's STEM workforce remains diverse and internationally linked—an important consideration given the international and cross-cultural collaborations that increasingly define the nation's inventive activity.

Finally, the platform-setting responsibility of the federal government requires that Washington **safeguard the integrity and efficiency of the patent system.** In this regard, while the patent system does not seem to be fundamentally broken in the way some scholars contend, few would say the system is optimally designed and operated—and it does appear vulnerable to abusive litigation.

Most simply, there is the problem of funding and staffing the patent office adequately enough to keep pace with the tremendous increase in patent applications and the increasing complexity of technology. Between 1975 and 1979, it took an average of 1.9 years for a patent application to be granted, but from 2007–2011, that pendency period increased to 3.2 years. This is recognized by the patent office and examiner staffing has recently increased with the goal of reducing pendency and improving the quality of examination.[132] Yet, the issue will need to be constantly revisited. The situation was elegantly stated by the head of the patent office in a report to congress—in 1886:

> "The field of invention is widening so rapidly and the distinctions which are constantly required to be made have become so nice in many instances that the greatest care and skill are required to determine accurately what is new and what is old. Each year the history of invention becomes more elaborate and complicated and no department of the Government more needs the services of men who are not only learned in the sciences but who have become familiar by constant association month by month and year by year with the histories written and unwritten of invention and the arts."[133]

The need is just as great today.

A more troubling aspect of the patent system is the role of non-practicing entities (NPEs): the so-called "troll" entities that are buying up patent portfolios with the sole purpose of extracting payments from productive companies through negotiation or litigation. Since NPEs are not producers, their revenue comes solely (or mostly) from the licensing and litigation of intellectual property, which gives them a strong incentive to issue legal challenges, while avoiding reputational repercussions from consumers. Not surprisingly, a raft of academic and journalistic accounts is increasingly suggesting that non-producers (along with spurious or hyper-strategic) patent suits are perverting the patenting system. Action is required.

A complete prohibition of NPEs' ability to bring up patent litigation disputes would go too far, however. Throughout U.S. history, patents have been monetized, providing an important spark to innovation.[134] In so far as small businesses cannot afford a legal defense staff to monitor possible value-diminishing infringements, NPEs can serve a useful function by increasing the value of inventions and minimizing infringement risk.[135] Yet, *parties that bring frivolous law suits against companies for the sole purpose of extracting money should be punished.* One proposal, introduced by Rep. Peter DeFazio (D-OR) would force the litigant to pay the full legal costs of the alleged infringer if the judge decides that there was no reasonable likelihood of success.[136] While attractive in spirit, the legislation would limit this provision to computer hardware and software patents, and there would be tremendous uncertainty as to whether or not an NPE claim would be deemed frivolous. For his part, Judge Richard Posner has proposed that assignees should lose their patent if they do not employ it in a product within a specified time period.[137] Such a reform has merit on the surface but it would substantially limit the ability of inventors to monetize their work. For these reasons, legislation should allow NPEs to defend patent rights like other owners, while still recognizing their uniquely perverse incentives to litigate.

This all points to an alternative proposal. NPEs should be prohibited from initiating litigation or legal threats of any kind related to a patent claim until their claim has first been assessed and approved as valid by a patent authority, such as the Patent Trial and Review Board. An expert judge could be charged with assessing the merits of the infringement claim, on a preliminary and ex-parte only basis (meaning between the owner and the judge), and whether or not the owner can proceed with legal action (without taking a view as to whether or not the owner should win redress). This review would largely free productive non-infringing companies from having to respond to egregious claims made by NPEs, and it would only compel them to settle or make their case in court after an initial screen. NPEs that pursued threatening action without acquiring the needed pre-approval would have to pay steep fines to the U.S. patent office and to the company it harassed and would forfeit ownership of the patent in question, which would go to the public domain. To insure that this system is not flooded with a huge case load from NPEs, moreover, the judge would also have the power to refer the patent back to the USPTO for re-examination, including the possible rejection and refinement of claims. For the purposes of such legislation, NPEs subject to this regulation could be deemed "patent monetization entities" and defined in the following manner: *Patent owning for-profit businesses that do not earn the majority of their revenue through the sale of products supported by patents and have no plans to do so within two years.*[138] This definition would exclude universities, government labs, tech companies, and start-ups, which could prove their intention to shift revenue to the sale of patented products by submitting formal plans used to raise capital.[139] Details would have to be sorted out by patent law experts, but these reforms, or others like them, could very well end the troll problem, while preserving the market for patents and the integrity of the patent system.

Regional and state leadership

And yet, while many innovation dynamics are national and boundary crossing and so require federal nurturing, the fact remains that the innovation process turns out to be intensely localized.

More than traditional industries, the innovation economy has an inherent tendency toward geographical clustering. In keeping with that, this report has demonstrated the intense concentration of U.S. innovative activity not just in U.S. metropolitan areas but in a relatively narrow sub-set of those metros. There, in places like Boston or San Jose, the presence of strong research universities, a scientifically educated workforce, and innovative industries is driving intense patenting activity and strong economic performance even as the absence of those factors in other metros (like McAllen, Las Vegas, or New Orleans) leaves them lagging. All of which suggests the critical role and compelling interest the nation's metropolitan areas and their states have in attending to the regional underpinnings of the U.S. innovation economy. Positioned close to the institutions, firms, and people whose interactions drive invention, U.S. regions and their states possess critical leverage in convening, aligning, and supporting the relevant local actors so as to maximize the economic yield of their exchanges.

Accordingly, all metropolitan and state leaders have the means and positioning to enhance U.S. innovative activity from the "bottom up." A crucial catalyzing role that regional and state leaders must play is to **promote, convene, and inform local efforts to understand and bolster the regional innovation system and track performance.** Work to *employ the bully pulpit* to talk up the importance of innovation and regional and state economic development can incite action and engage disparate actors.[140] Moreover, such signaling can help *convene regional actors* and catalyze the critical collaborative exchanges among the regional businesses, industry associations, universities, governments, and other entities that comprise the local innovation system. For example, regions such as New York, Northeast Ohio, and Seattle and states as diverse as Colorado, Nevada, New York, and Tennessee are currently advancing concerted efforts to highlight the centrality of regional innovation systems and to call forth regional innovation cluster activities to intensify their action.[141] In this connection, intent regions and states should move aggressively to use data and analysis to objectively assess the strengths and weaknesses, competitive prospects, and specific needs of local innovation systems.[142]

Regions and especially states, informed by strong analytics, may also need to **target resources to address discrete gaps in regional innovation systems' performance**. In this respect, metropolitan and state interventions should be pursued judiciously to focus on attacking specific system barriers to inventiveness. That means they need to: support top-quality knowledge infrastructure, both at the university and K-12 level; mitigate market failures in finance, speed knowledge transfer; promote its commercialization; and work to attend to enhance the flow of inventive exchange in regional innovation clusters.

To give a few concrete examples, the Entrepreneurial Development Center, an "accelerator" in Des Moines, Iowa helps local start-ups get funding and commercialize by providing something like a social network for inventors, investors, and entrepreneurs.[143] Another organization there provides start-up funding, using private and public dollars.[144] At the state level, governments outside of Massachusetts and California can bolster relatively thin lending markets by augmenting private sector financing without eliminating risk. The Small Business Jobs Act of 2010 allowed the Treasury Department to spend approximately $1.5 billion to support state lending policies—like venture capital funds—worth an estimated $15 billion. As of early 2012, 47 states were participating in this program, called the State Small Business Credit Initiative.[145]

Investments to *construct and maintain topflight knowledge infrastructure,* including strong education and training systems, loom large. This report has documented the critical role of universities and a well-trained STEM workforce in inventive activity. Therefore, strategic investments in universities' top science and technology programs; STEM-related education at all levels; and workforce training all amount to foundational support for the innovation process. Yet in this connection, these investments must be accompanied by constant nudges toward institutional innovation—new ways of developing R&D preeminence (as through business partnerships and targeted "star scholar" initiatives); new industry-oriented STEM training models; new STEM education options, such as "STEM high schools" and career and technical education. The same experimentation must also be brought to bear as regions and states work together to spur innovation more directly. With the economy increasingly dependent on innovation and higher education central to it many regions and states moved assertively to construct more strategic focused innovation capacity. Mayors and governors have invested directly in specific R&D initiatives; matched federal research funding in areas important to regional business development; or even created large, multi-year "innovation" funds to underwrite research in targeted areas fundamental to a region's economic development. Likewise, they have established a wide range of institutions and entities (research parks, centers of excellence, applied research hubs) aimed at linking higher education to regional innovation goals and industry. Such programs can be helpful in many regions, especially those with serious demonstrable gaps in their university research base. But what will be equally and perhaps more catalytic in regions with sound existing research activities will be moves to *speed knowledge transfer out of universities and into the regional private economy* through targeted programs that seek to actively reveal new intellectual property; streamline its marketing and licensing; and systematically incentivize universities to maximize outward knowledge flow.[146] In all of this much more information, reporting, transparency, and accountability is needed and will likely need to be incentivized by states.[147] Also needed in many regions are mechanisms to *accelerate the commercialization of intellectual property,* particularly through improvements in new firms' access to risk capital. Such access to capital is frequently spotty, given the geographical concentration of private seed and venture capital sources and the numerous risks that investors face. For that reason, regions and states can improve the availability of early stage capital in their innovation reasons by starting their own funding programs, launching prize competitions, investing their own money, or taking steps to encourage "angel" investments. Programs that make available modest grants for IP discovery, proof-of-concept development, and early commercialization work are proliferating and in many regions address a critical need.

Yet more action may be required: Regions and their states frequently need to take steps to **intensify the workings of regional innovation clusters**. Strong regional clusters—characterized by strong social interactions and dynamic knowledge spillovers—have been shown to foster and accelerate innovation and entrepreneurship.[148] Yet for numerous reasons the knowledge exchanges within a particular cluster in a particular region may occur at sub-optimal levels. Habits, location, institutional barriers: All of these may mean that researchers and firms with similar interests may exist near each other but have little formal interaction. And so regions or states—working with relevant regional scholarly, professional, and business organizations—may seek to intensify the level of knowledge exchange in the region. Leaders and organizations may *convene or help to better organize relevant knowledge and industry networks.* Such networks may facilitate work to *identify institutional or resource deficiencies and design responses.* And beyond that, cities, regional development organizations, or states may want to *provide small matching grants to help support and expand cluster capacity and initiatives*.[149] Through such grants cities, regional organizations, and states can help regional knowledge networks cohere, connect with industry, and begin to collaborate on innovation problems of shared interest. For their part, some cities are even beginning to delineate neighborhood-scale "innovation districts" to facilitate innovation through place-based city-making approaches.[150]

Finally, regions and states need to **link and align their existing policies, programs, and initiatives in service of their regional innovation strategies.** Direct, targeted and discrete new "innovation" initiatives clearly have a role in accelerating innovation. Institutional innovation will be critical going forward. However, significant impact can also come if cities, regions, and states *better organize existing programs*. Whether it be higher-ed planning and workforce training delivery, manufacturing or place-making policy, existing innovation-relevant programs should be aligned to advance the overall innovation project. Are educational programs cultivating a sense of discovery along with STEM facility? Does tax policy encourage or discourage inventive activity? Do available grant programs add up to a system for supporting discovery and commercialization or are they simply isolated programs? What about land-use and urban development policies? Are these creating dense environments for knowledge exchange or dismantling them? Such are the sort of questions that require serious consideration as regional and state leaders seek to tune their myriad existing activities to the innovation project. Which is to say: Like cluster development, innovation strategy is less a specific program than a framework through which to shape and coordinate the full range of local and state action.

* * *

Despite the Great Recession, the intensity of invention in the United States is high compared to both the rest of the world and its own history—propelling the growth and development the nation's great metropolitan areas. High quality inventions across a number of industries are transforming regions and creating spectacular wealth. Yet, many areas lack these assets and suffer as their less inventive firms stagnate or fail to generate high-paying jobs. Rather than looking to the consumer-driven inducements of entertainment, tourism, and retail to revive growth, regions and their states can turn their investments to more valuable and sustainable efforts to promote prosperity. The inventive capacity of regions is noticeably strengthened through educational attainment in STEM fields, academic training and research, collaboration, and public sector investments in basic and applied R&D. Each region will have to craft its own strategy to the specific shortcomings it faces. Given the growing size and geographic diversity of global markets, the rewards for successful invention have never been greater. If living standards in the United States are to progress at historic rates, the effort must rise to the occasion.

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