# New Ideas in the Air: Cities and Economic Growth

BY GERALD A. CARLINO

Most countries make sustained economic growth a principal policy objective. While many factors contribute to growth, economists believe that educating workers plays a critical role. Individuals invest in education because of the expected benefits to themselves or their children, such as higher earnings. But such private investment can increase the productivity of others as well. For example, the collaborative effort of many educated workers in a common enterprise may lead to invention and innovation that sustains the growth of the enterprise. Some economists believe there is an important link between national economic growth and the concentration of more highly educated people in cities.[1] These economists argue that the knowledge spillovers associated with increased education can actually serve as an engine of growth for local and national economies. They also argue that the concentration of people in cities enhances these spillovers by creating an environment in which ideas flow quickly amid face-to-face contact.

As far back as 1890, Sir Alfred Marshall described cities as having ideas "in the air." In Marshall's view, knowledge spillovers are the unintended transmission of knowledge that occurs among individuals and organizations, as opposed to the conscious sharing and exchange of knowledge. For example, as pointed out by AnnaLee Saxenian, although there is intense competition in California's Silicon Valley, a remarkable degree of knowledge spillover occurs.

In the first half of the 20th century, American cities contributed to economic efficiency and growth when the U.S. economy was based on the production of goods. Today's cities, despite their well-known drawbacks such as congestion, contribute to the efficient production of knowledge in the new innovation-based economy.

## KNOWLEDGE SPILLOVERS AND GROWTH

Economic growth has many facets, but a key one is that the value of real output per hour worked in the U.S. has increased dramatically over the years: In 2012, the value of output per hour worked was more than four times the value of output per hour in 1950. This increase in worker productivity is the hallmark of growth. What are the main reasons for the increase in worker productivity? The two key causes are increases in the amount of capital per worker and technological progress. Capital goods are nonfinancial assets such as factories, office buildings, and machinery used to produce goods and services. The capital stock refers to the total amount of physical capital available to an economy at a given point in time. Technological progress can take the form of either product innovation or process innovation. For example, the moving assembly line and interchangeable parts used by Henry Ford in 1913 to produce autos is an example of process innovation. Groupon is a more recent example of process innovation that has changed the way merchants attract customers and how customers find merchants. The Swiffer is an example of product innovation. Unlike traditional dust mops that must be laundered, Swiffer refills are discarded.

In an influential paper, the economist Robert Solow computed that 51 percent of U.S. output growth from 1909 to 1949 can be attributed to technological progress, while growth in the capital stock accounted for only 11 percent of the increase in growth. Despite the fact that technological progress is measured as a residual, Solow's work made it abundantly clear that the growth in real income per worker is far too large to be accounted for by growth in the capital stock. In the absence of technological progress, the economy settles into a steady state in which out-

[1] Unless otherwise indicated, city and metropolitan area are being used to designate a metropolitan statistical area (MSA), which is a geographic area delineated by the U.S. Office of Management and Budget that combines a densely populated nucleus with adjacent communities that have a high degree of economic integration with the nucleus.

**Gerald A. Carlino** is a senior economic advisor and economist at the Federal Reserve Bank of Philadelphia. The views expressed in this article are not necessarily those of the Federal Reserve. This article and other Philadelphia Fed research and reports are available at www.philadelphiafed.org/research-and-data/publications.

put per worker and capital per worker remain constant through time; that is, the standard of living does not change. However, improvements due to, say, a new production technology can lead to a new, higher steady state. In Solow's model, the rate of long-run growth of the economy is determined by the rate of technological progress, which is taken as given, providing no explanation for productivity improvements. Since the rate of productivity growth is the most important determinant of long-run growth, treating such an important factor as given leaves many unanswered questions.[2]

Beginning in the mid-1980s, economists, most notably Paul Romer and Robert Lucas, expanded on Solow's framework to include explanations for productivity growth, referred to as the *new growth theory*. One version of the new growth theory focused on human capital — the knowledge and skills of people — as the engine of growth. As people enhance their human capital, they not only become better workers, they also contribute to economic growth by developing new goods and new ways to produce existing goods. Education is one way individuals add to their human capital. But as individuals accumulate knowledge, they also contribute to the productivity of many other individuals with whom they have contact either directly or indirectly. Thus, the accumulation of knowledge by one person has a positive effect on the productivity of others.

Interestingly, the new theory of growth helped to establish a link between cities and innovation. Knowledge flows are much more easily transmitted among individuals located in a common area, such as a city. This is especially true for "tacit" knowledge, which is highly contextual and hard to codify. The best way to transmit tacit knowledge is through frequent face-to-face contact. Importantly, cities not only facilitate the transmission of knowledge among people and firms; cities also promote the continuous creation of new ideas, which is an important ingredient in the growth process. In this view, growth can be sustained by the continuing development and improvement of the human capital that generates knowledge spillovers. Although the channels through which knowledge spillovers are transmitted are not well understood, the dense concentration of people and firms in cities creates an environment in which new ideas travel quickly.

## WHAT'S THE EVIDENCE?

Since knowledge spillovers are invisible, they cannot be directly measured. The challenge is to come up with a way to measure them indirectly. There are two main empirical approaches to identifying spillovers in regions: through their effects on wages and on patent citations.

**Studies based on wages.** Lucas suggests that the level of productivity in a location depends on the *average* level of human capital in that location. Education is an important aspect of human capital, and many studies use some measure of educational attainment as a proxy for the human capital stock of cities. Accordingly, a productivity spillover occurs when the body of educated workers in a city makes other workers in that city more productive. The share of the adult population age 25 and older with a college education differs dramatically across cities (see Table 1). The college-educated share in 2010 runs from a high of almost 28 percent in the Raleigh, NC, metro area to a low of about 9 percent in the Visalia, CA, metro area — a threefold differential. In his 2012 book, Enrico Moretti shows that there is an even bigger differential across cities (by a factor of 5) in the college-educated share among *workers*. If a higher college-educated share (the proxy for knowledge spillovers) makes workers more productive, this increased productivity will be reflected in higher wages. Thus, the vast majority of studies attempt to measure the additional earnings that similar workers — in terms of age, education, occupation, industry, and experience — receive as the share of college graduates in their city increases.[3] Importantly, these studies find that each additional year of average education increases a region's expected wages by 1 percent to 5 percent.[4]

Antonio Ciccone and Giovanni Peri point out that an increase in the share of highly skilled workers in a city

[2] Since 1950, real U.S. GDP has grown at an average annual rate of 3.2 percent. Applying the Solow approach and using the rule of thumb that capital receives about one-third of national output and labor two-thirds, growth in the stock of capital (net of depreciation) would account for only 0.34 percentage point of real GDP growth. Another 1.18 percentage points could be attributed to growth in the labor input and 1.7 percentage points to technological progress. Put differently, growth in the capital stock accounts for only about 11 percent of the output growth since 1950 and growth in labor explains 37 percent, while over 50 percent is accounted for by technological change (the Solow residual).

[3] See the studies by Rauch; Acemoglu and Angrist; Ciccone and Peri; Moretti, 2004a; and Rosenthal and Strange.

[4] Using 1980 census data, Rauch estimates that each additional year of average education in a city increases expected wages 3 to 5 percent. But do the most skilled individuals gravitate to cities that offer higher wages? Or do high average wages in cities improve worker productivity, leading to higher wages? Recent studies attempting to control for reverse causality find that a one-year increase in average schooling is associated with about a 1 to 2 percent increase in average wages. In addition, rents must be higher in more productive cities; otherwise, workers could increase their welfare and firms would increase profits by moving to these cities. That is, increases in productivity will show up as some combination of higher wages and higher rents. Few studies have looked for evidence of knowledge spillovers in urban land markets, as land rent data are not generally available. One exception is a study by Jesse Shapiro, which finds that a 10 percent increase in the share of college-educated workers in metropolitan areas led to a 2.4 percent increase in wages and a 1.2 percent increase in rents from 1940 to 1990.

could increase the wages of less-skilled workers in that city for reasons other than knowledge spillovers. Highly skilled and less-skilled workers can *complement* one another in production, in the sense that an increase in one type of worker can increase the productivity of the other type of worker. Thus, an increase in the share of highly skilled workers in a geographic area will increase the productivity of less-skilled workers in that area, just as having more or better machines to work with increases worker productivity. Given this increase in overall productivity, firms can offer higher wages to less-skilled workers. The question is, how much of the increase in the wages of less-skilled workers as a result of having more highly skilled workers in the city is due to knowledge spillovers and how much is due to complementarities? Holding the labor force skill mix constant over the period 1970-90, Ciccone and Peri find no evidence of a return to a one-year increase in average schooling once they account for complementarities between highly educated and less-educated workers. An interesting study by Moretti reports that being around a lot of highly skilled workers can be especially beneficial for less-skilled workers. He finds that a 1 percent increase in a city's share of college graduates increases the wages of college graduates by only about 0.5 percent but increases the wages of high school dropouts by almost 2 percent, while raising the wages of high school graduates by roughly 4.5 percent.

**Studies based on patents.** Although wage studies are useful for estimating the magnitude of knowledge spillovers, they treat differences in average educational attainment from one city to another as static conditions, telling us little about the forces driving economic growth.[5] Because the accumulation of knowledge is needed for economic growth, studies that look at research and development and patent-

## TABLE 1

### College Share Differs Widely Among Metro Areas

| Rank | Top 10 | Percent* |
|---|---|---|
| 1 | Raleigh-Cary, NC | 27.8 |
| 2 | San Francisco-Oakland, CA | 26.5 |
| 3 | Madison, WI | 26.0 |
| 4 | Austin-Round Rock-San Marcos, TX | 25.7 |
| 5 | San Jose-Sunnyvale-Santa Clara, CA | 25.6 |
| 6 | Minneapolis-St. Paul-Bloomington, MN-WI | 25.4 |
| 7 | Ann Arbor, MI | 25.4 |
| 8 | Provo-Orem, UT | 25.2 |
| 9 | Denver-Aurora-Broomfield, CO | 25.0 |
| 10 | Bridgeport-Stamford-Norwalk, CT | 24.8 |
| 44 | Philadelphia-Camden-Wilmington, PA-NJ-DE-MD | 20.1 |
| — | U.S. Average | 17.8 |
| **Rank** | **Bottom 10** | **Percent*** |
| 148 | Stockton, CA | 12.1 |
| 149 | Hickory-Lenoir-Morganton, NC | 11.9 |
| 150 | Charleston, WV | 11.5 |
| 151 | McAllen-Edinburg-Mission, TX | 11.3 |
| 152 | Beaumont-Port Arthur, TX | 10.9 |
| 153 | Ocala, FL | 10.8 |
| 154 | Modesto, CA | 10.6 |
| 155 | Brownsville-Harlingen, TX | 10.3 |
| 156 | Bakersfield-Delano, CA | 9.9 |
| 157 | Visalia-Porterville, CA | 8.9 |

* Share of the population with college degrees in metro areas with at least 200,000 residents age 25 and older.

Source: American Community Survey, U.S. Census Bureau.

[5] A primary advantage of large cities is that they facilitate learning, thus leading individual workers to develop their human capital over time (a dynamic effect). Glaeser and Maré (2001) find that the effect on workers' wages is small when first they arrive in a new city (static effect) but that wages tend to grow over time as workers accumulate human capital (dynamic effect). Several studies confirm that wages grow faster in larger cities (Baum-Snow and Pavan, 2013; De la Roca and Puga, 2012; Wang, 2014). Using a sample of Spanish workers during 2004-09, De la Roca and Puga (2012) find that one-half of the premium is static — that is, workers receive it upon arriving in a city — while the other half accumulates over time as part of the dynamic benefits of learning. Wang (2014) finds that college-educated workers who spend their early years in large cities tend to have faster wage growth.

ing activity can be more informative about the role of knowledge spillovers in growth. In my research with Satyajit Chatterjee and Robert Hunt, we find that the share of the population with a college degree is by far the most important factor in explaining patenting activity in cities in the 1990s. We find that a 10 percent increase in the college share is associated with an 8.6 percent increase in patents per capita during the 1990s.

Firms undertake R&D to realize productivity gains through innovations. Since R&D is an input into the production of patents, patent citations provide a measure of knowledge spillovers. Patent citations trace knowledge flows in that a citation in a patent application to earlier patents indicates that inventors knew about and used information contained in earlier patents. Adam Jaffe, Manuel Trajtenberg, and Rebecca Henderson point out that inventors are likely to be more aware of patents awarded to inventors who are geographically close to them. If knowledge spillovers are localized within a given metropolitan area, then citations to patents within a given metropolitan area should come disproportionately from other inventors who are located within that metropolitan area. Since every patent lists the names, hometowns, and zip codes of the inventors named in the patent, one inventor's proximity to another is easily determined.

However, Jaffe and his coauthors are concerned that a citation to nearby inventors may be due to reasons other than knowledge spillovers. The concern is that technologically related activity may be clustered geographically for reasons unrelated to knowledge spillovers. For example, the semiconductor industry could have concentrated in Silicon Valley because that location was a source of venture capital. So, for each citation, Jaffe and his coauthors choose a control citation that is technologically similar to the original citation and was made around the same time. Jaffe and his coauthors find a significant "home bias." That is, patent citations (excluding self-citations) are two to six times more likely than control patents to come from the same metropolitan area.[6]

Their finding provides strong evidence for knowledge spillovers among inventors. Indeed, the magnitude of the spillover may be understated. Metropolitan areas may not be the most appropriate geographic area of measurement, as their boundaries are determined by worker commuting distances rather than by the concentration of inventors and therefore are not well suited for capturing the knowledge spillovers among individuals engaged in innovative activity. There is mounting evidence that the transmission of knowledge rapidly deteriorates the farther one gets from the source of that knowledge. For example, Mohammad Arzaghi and Vernon Henderson look at the location pattern of firms in the advertising industry in Manhattan. They show that for an ad agency, knowledge spillovers and the benefits of networking with nearby agencies are extensive, but the benefits dissipate quickly with distance from other ad agencies and are gone after roughly one-half mile. Since knowledge spillovers appear to be highly localized, nearby inventors and firms can introduce innovations faster than rival inventors located elsewhere can. There is historical evidence on the highly localized nature of knowledge spillovers, too. In 17th century England, people gathered in coffeehouses to share ideas, with different coffeehouses attracting specialized clienteles. The London Stock Exchange began life in 1698 in a coffeehouse where merchants met. Another coffeehouse where shippers and traders met became recognized as the place to obtain marine insurance and gave rise to Lloyd's.[7]

In my research with Jake Carr, Robert Hunt, and Tony Smith, we describe how the geographic concentration of R&D labs can be used to determine more appropriate geographic boundaries in which knowledge spillovers are most likely to occur. For example, we found a cluster of R&D labs centered on Cambridge, MA, and a cluster in Silicon Valley, among others. Similar to Jaffe and his coauthors, we find evidence of a significant home bias in patent citations (excluding self-citations) in most of the clusters we identified. We find that patent citations are over 12 times more likely to come from the San Jose, CA, cluster and more than eight times more likely to come from the Cambridge cluster as from their respective control patents chosen to match the geographic concentration of technologically related activities. This finding provides not only evidence of localized knowledge spillovers in patent citations but also much stronger evidence than reported in prior studies.[8]

Patents have well-known problems as indicators of inventive activity in

[6] See my article with Jake K. Carr for details on the technique used by Jaffe and his coauthors. Peter Thompson and Melanie Fox-Kean report that Jaffe and his coauthors' findings are sensitive to the way the control patents are selected. By using much broader technology classifications to select the control patents, Thompson and Fox-Kean find no evidence supporting localization of knowledge spillovers at either the state or metropolitan area level. Since knowledge spillovers tend to be highly localized within a metropolitan area, states and metro areas are not the appropriate geographies for studying them. Yasusada Murata and his coauthors instead use a distance-based approach and find substantial evidence supporting the localization of patent citations even when very broad technological classifications are used to select the control patents.

[7] Tom Standage, "Social Networking in the 1600s," *New York Times*, June 23, 2013.

[8] See my article with Jake K. Carr for details on the clustering of R&D labs.

that not all inventions are patented. Firms can choose other ways to protect their profits from inventions such as maintaining trade secrets and being first to bring a new product to market. Another concern is that the patent examiners themselves routinely add citations to patent applications. Citations added by examiners are unlikely to reflect knowledge flows. Jeff Lin avoids this potential problem by looking for evidence of knowledge spillovers in patent interferences, which are administrative proceedings to determine which applicant is entitled to the patent when multiple applications are submitted for the same invention. The basic idea is that inventors involved in an interference are likely to share certain knowledge, so patent interferences may offer evidence of knowledge spillovers among inventors. If localized knowledge spillovers are important, we should see that inventors in close geographic proximity should be disproportionately involved in interferences. Lin finds that patent interferences are more likely to be observed between inventors located close to one another as opposed to those located farther apart — evidence that common knowledge inputs among independent inventors are highly localized.

In another study, Lin looked at which cities are the most creative, in that they generate "new work," measured by jobs that did not exist a decade earlier. The idea, which dates from Jane Jacobs, is that having a higher percentage of educated workers in a city leads to greater creativity and to the invention of new ways of working. Lin finds that 5 percent to 8 percent of U.S. workers are engaged in new work, but that the percentage is higher in cities with a higher-than-average density of college graduates and a more diverse set of industries.

**Other studies.** Some studies have looked for evidence of knowledge spillovers by considering how differences in education across cities translate into differences in firms' productivity across cities. The idea is that firms situated in cities with high human capital will be able to produce more output using the same level of inputs compared with similar firms located in cities with low human capital. Moretti (2004b) looks at the growth in the productivity of manufacturing plants during the 1980s and finds that, on average, human capital spillovers account for a meager 0.1 percent increase in output per year, or about $10,000 per year.

Looking at population growth and the growth in income in cities from 1960 to 1990, Ed Glaeser, José Scheinkman, and Andrei Shleifer find that cities with high median years of schooling for persons age 25 and older grew faster. A one-year increase in median years of schooling in 1960 increased subsequent income growth by almost 3 percent. Similarly, Jesse Shapiro finds that from 1940 to 1990, a 10 percent increase in a metropolitan area's share of college-educated residents (from, say, 20 percent to 22 percent) raised employment growth by approximately 2 percent.

In sum, the bulk of the evidence supports the existence of localized knowledge spillovers. But knowledge flows are invisible, so we do not observe exactly how knowledge flows among individuals. A central limitation of these studies is that none explore the ways in which knowledge is transmitted among individuals living in close geographic proximity. So far, we have stressed the role of nonmarket-based geographic ties in spreading knowledge, especially tacit knowledge that cannot be easily codified and distributed via the usual media sources. Perhaps people can share tacit knowledge through professional or social networks. But, as Vernon Henderson has asked, how do these networks form, how are members accepted, and how do spatial patterns form? Glaeser suggests a mechanism for learning in cities when young people move to big cities to learn from experienced workers. Think of a recent M.B.A. who moves to Wall Street to learn from experienced brokers and traders.

Alternatively, geographic proximity may facilitate the exchange of knowledge through contractual and market-based channels. One way knowledge could spread is when skilled workers move from one firm to another, especially within the same city. This type of knowledge transfer is not a spillover to the extent that these workers are compensated for the knowledge they bring to their new firms. But there is reason to believe that such sharing of ideas through mobility is limited, as most employers include nondisclosure and noncompete clauses in employment contracts to protect proprietary knowledge from leaking to another firm. Additionally, Ariel Pakes and Shmuel Nitzan show that stock options give employees a strong incentive to remain with their current employers. The courts in most states deem noncompete clauses to be legally binding contracts provided they contain reasonable limitations on the geographic area and time period in which an employee may not compete. California is an important exception; its courts have generally been reluctant to enforce noncompete clauses, which have been held to violate freedom

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of competition and unduly restrict people's ability to seek work wherever they choose. Even so, Bruce Fallick, Charles Fleischman, and James Rebitzer find that, outside of the computer industry in Silicon Valley, job-hopping rates for college-educated males are no higher than in other states.

## CONCLUSION

What, if anything, should local policymakers do to stimulate local innovative activity? The answer depends, in part, on who benefits from that local innovative activity. A metropolitan area might be highly inventive, but if the benefits of this inventive climate — that is, the successful commercialization of its inventions — occur largely in other regions, local policymakers might have too little incentive to support local inventive activity by offering tax breaks or other financial incentives to attract R&D labs and innovative startups. That wider benefit that comes from innovation suggests a role for federal support to foster local innovation. But this begs the questions: What type of support would have the most impact? And who should decide how and where support should be provided? Although it is difficult to make policy recommendations grounded in the evidence, we can offer broad suggestions. The most significant levers that policymakers at any level of government should consider are ones that influence the development of human capital. The concentration of individuals with high human capital in cities leads to knowledge spillovers among these individuals, which in turn leads to new ideas and economic growth. My research with Chatterjee and Hunt shows that education is by far the most important variable in explaining the overall rate of inventive activity in cities. Glaeser and his coauthors suggest that local policymakers need to focus on lifestyle enhancements such as good schools, public parks, low crime, and clean streets, because they are important in attracting and retaining highly educated workers.

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