150 Years of the Geography of Innovation*

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Abstract

Innovation has long been seen as central to long-term regional growth. Due to the absence of comprehensive data on the geography of innovation covering long time periods, quantifying long-term innovation-development linkages has been challenging. We use newly available patent data from the United States coded to consistent geographies over 150 years to document changing patterns in the geography of innovation. Our analysis reveals three findings. First, the high levels of spatial concentration of innovation today are similar to those in the decades after the Civil War. Second, changes in share of the top 1% locations' innovation drive national spatial concentration trends after 1945. Third, regional innovation leadership displays persistence, but the strength of persistence appears to have fallen over time. We relate our analysis recent findings in the literature and suggest promising avenues for future inquiry.

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1 Introduction

We have witnessed significant changes in economic geography recently. Locations that had very similar income levels or house prices in the 1960's are now quite different. Moretti (2012) terms this the "Great Divergence" and sees the rise of innovation hubs playing a central role. While much attention has been given to changes in the geography of innovation over recent decades, longer term questions remain unanswered. Are today's levels of spatial concentration of innovation historically unprecedented? Which locations drive changes in the spatial concentration of innovation over time? How persistent is regional innovation leadership? Has persistence increased or decreased over time? This paper aims to answer these questions.

Silicon Valley or Route 128 are synonymous with frontier innovation today. It is easy to forget that other cities have defined the technological frontier in the past. Cleveland is seen today as a declining rustbelt city, yet in the late 1800's it was a thriving hot bed of high tech startups. Cleveland's location gave it convenient access to Lake Superior iron ore and provided leadership in the manufacturing of steel, machine tools, automobiles, and electrical machinery (N. R. Lamoreaux, Levenstein, & Sokoloff, 2004) — technologies that defined the Second Industrial Revolution. Detroit's automotive technological leadership built from applying ship motor expertise to a new area lead it to be a high tech leader of it's time in similar fashion (E. Glaeser, 2012).

The decline of Cleveland and Detroit and the rise of Silicon Valley represent powerful examples of how technological leadership can change, and the consequences for their communities. But, how representative are these examples? Because of limitations in the measurement of where innovation happens over the long term, drawing conclusions about the relationship between the regional innovation and regional development has been difficult. In this paper we use newly available data that geographically locates every US patent from 1866 to 2016 to quantify how the geography of innovation has changed over the last 150 years.[1]

[1]Patents are a heavily studied source to understand trends in innovation. It is important to note however

Why might the geography of innovation change? Changes in the location of innovation suppliers (human capital and research funding), innovation customers (corporate head offices and governments), and the nature of the regional innovation production function (knowledge spillovers and frictions in knowledge diffusion) are likely key factors. We do not seek to quantify the importance of these factors in this paper. We simply document the trends and leave disentangling the driving forces to future work.

Our analysis delivers three main results. While recent trends suggest that innovation has become increasingly spatially concentrated over time, our analysis shows a relationship that is far from monotonic over the long term. The period from the end of the Civil War to roughly 1905 is one of largely uninterrupted declining spatial concentration. From about 1905 to the end of World War II in 1945, spatial concentration is largely stagnant. In the immediate aftermath of World War II, the spatial concentration of invention drops sharply, and then continues to decline until about 1990. Finally, from 1990 to the present, spatial concentration increases dramatically. Spatial innovation concentration today is not unprecedented; it is similar to the post Civil War period.

Second, we examine which places are driving the aggregate changes in the spatial concentration of innovation. The post World War II drop and then sharp growth after 1990 in the spatial concentration are driven by the top 1% of innovation locations. Innovation in elite locations like the San Francisco Bay Area, Seattle, Los Angeles, Boston, and Chicago are key drivers of national trends in spatial concentration.

Increasing returns to scale and network effects are central to both urban economics and market leadership through technology. But how persistent is regional technological leadership? Will Silicon Valley remain the undisputed technology leader in 50 years or it is likely to suffer the same fate as Cleveland? Our analysis shows moderate persistence in leadership—areas with higher shares of national patents in 1866 do have higher shares of national patents in 2016. Innovation persistence, however, appears to be weakening over time.

that not all innovations are patented and changes in patent policy may affect patent counts even if the rate of innovation remains unchanged. See Moser (2016) for more discussion.

2 Geographically Linked Patent Data

Until recently, geographically linked U.S. patent data was only available in digital form from 1976 onward, making large scale historical analyses of patenting difficult.[2] In recent years, however, several research teams have compiled historical patent datasets comparable in quality and completeness to modern-day patent records; Andrews (2020b) provides an overview of these new data sources. Several studies have used these large scale patent datasets to examine long-run dynamics of U.S. patenting (Akcigit, Grigsby, & Nicholas, 2017; Berkes & Gaetani, 2018; Kelly, Papanikolaou, Seru, & Taddy, 2020; Sarada, Andrews, & Ziebarth, 2019).

For this paper, we use patent data from the Comprehensive Universe of U.S. Patents (CUSP, see Berkes, 2018), which contains information on all U.S. patents from 1836 to 2016. Crucially for our purposes, the CUSP data contains the location of each inventor listed on each patent. The geographical information is obtained by extracting the name of each inventor's town, county, and state from patent text, determines the latitude and longitude of that location, and then assigning that location to its current U.S. county. This last step is important in light of changes in municipal and county boundaries over time.

County population data over time come from Manson, Schroeder, Riper, and Ruggles (2018). Since historical population counts are only available during decennial census years, we linearly interpolate population for years between census years; results are insensitive to alternative methods of interpolation or to keeping data only from census years. We conduct our analysis of urban areas by aggregating counties to commuting zones, using definitions of commuting zones provided by the U.S. Department of Agriculture Economic Research Service for the year 2000.[3]

[2]Patent data has been frequently employed in the study of the geography of innovation and agglomeration following the seminal study of Jaffe, Trajtenberg, and Henderson, 1993

[3]See https://www.ers.usda.gov/data-products/commuting-zones-and-labor-market-areas/.

3 Spatial Concentration of Innovation

Our measure of the spatial concentration of innovation is based on the "dartboard" approach of Ellison and Glaeser (1997). The idea is to compare the observed spatial distribution of innovation to what would happen if innovation was randomly distributed across space according to the population distribution to capture the spatial concentration of innovation intensity. The dartboard innovation intensity concentration index is given by

$$Concentration_t = \frac{Gini_t}{1 - \sum_{z=1}^{Z} SharePop_{zt}^2} \tag{1}$$

where

$$Gini_t = \sum_{z=1}^{Z} (SharePat_{zt} - SharePop_{zt})^2$$

for each year t and all geographic areas $z \in Z$. If all patenting occurs in one geographic area in year t, then $Concentration_t \approx 1$, while if each geographic area has the same share of patents as it does population in year t, then $Concentration_t = 0$.[4]

In Figure 1 we plot our dartboard spatial concentration of innovation index over time using three different geographic areas. We choose to begin our analysis in 1866 to exclude disruptions from the civil war. In panel (a), we plot changing concentration across commuting zones. Observed changes in the spatial concentration of innovation may plausibly be driven

[4] In the original Ellison and Glaeser (1997) model, N firms sequentially choose among the Z locations, and so the concentration measure must be adjusted to account for the different sizes of firms. In our context, if each of N inventors sequentially chooses a location, the dartboard measure becomes:

$$Concentration_t = \frac{Gini_t - (1 - \sum_{z=1}^{Z} SharePop_z^2) \sum_{i=1}^{N} SharePat_{it}^2}{(1 - \sum_{z=1}^{Z} SharePop_{zt}^2)(1 - \sum_{i=1}^{N} SharePat_{it}^2)},$$

where $SharePat_i$ is the share of total patents belonging to inventor i. In our case, we assume that each inventor makes a separate location decision for each patent, so that $SharePat_{it} \approx 0$ for each i and t. This is not an unreasonable assumption when inventors are highly geographically mobile. Adjusting the dartboard measure to account for the fact that different inventors are more or less prolific requires disambiguating inventor names across their patents. While these types of disambiguation exercises have been done for recent patents (Li et al., 2014; Monath & McCallum, 2015; Trajtenberg, Shiff, & Melamed, 2006), large scale disambiguation projects for historical patent data are still in nascent stages and so disambiguating inventors is beyond the scope of this paper.

by the territorial expansion of the U.S.; frontier areas which were nearly uninhabited in 1866 developed over time, which may drive down the concentration measure. To address this issue, in panel (b) we restrict our attention to a balanced panel of commuting zones consisting of locations that were part of states that had attained statehood prior to the start of the Civil War.[5] In panel (c), we plot the concentration of innovation at the county level, providing a finer level of geographic analysis that captures the fact that some of the changes in concentration may occur within commuting zones, for instance the rise of suburbanization. Regardless of which geographic measure we use, the concentration of innovation exhibits nearly identical patterns over time. Four distinct periods are apparent.

We next describe each period and discuss the forces may have shaped the observed patterns. We stress that the changes we describe are not driven by changes in population, but rather captures how invention changes beyond what we would expect based on the concentration of population.[6]

Declining Concentration, 1866-1905: The period from the end of the Civil War to roughly 1905 is one of largely uninterrupted declining concentration. This period falls within what Khan (2005) calls "the democratization of invention." One irony is that, while American invention was highly democratic in the sense of being open to individuals from any walk of life, at least in the early post-Civil War years these democratic inventors tended to hail from relatively few geographic locations.

What might explain the ensuing decline in spatial concentration? One constant since the middle of the 19^{th} century has been improvements in transportation and communication technologies. As it becomes cheaper to move people and ideas across space, we may expect to see invention occur in more places, leading to declining spatial concentration. Consistent with this, Perlman (2016) shows that the arrival of railroads to an area led to more local

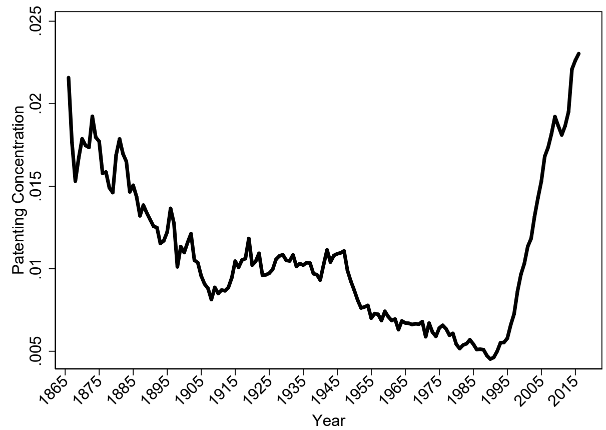
[5] More precisely, we do not include any states that achieved statehood after 1860. We therefore do not include any locations from Kansas, West Virginia, Nevada, Nebraska, Colorado, North Dakota, South Dakota, Montana, Washington, Idaho, Wyoming, Utah, Oklahoma, New Mexico, Arizona, Alaska, or Hawaii. Note especially that the balanced panel of commuting zones does not include Seattle, today once of the most innovative regions in the country.

[6] We find similar dynamics when plotting measures of concentration that ignore population completely, such as calculating a simple Herfindahl-Hirschman index of commuting zone patenting.

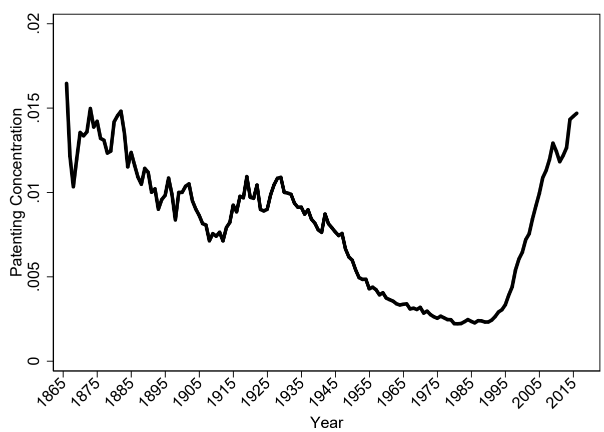
Figure 1: Patent Concentration

(a) Commuting Zones

(b) Balanced Panel of Commuting Zones



(c) Counties



Notes: Spatial concentration of U.S. patenting using the definition of concentration given in Eq. (1) for each year from 1866 to 2016. Panel (a) calculates concentration at the commuting zone level. Panel (b) uses a balanced panel of commuting zones consisting of locations in states that had obtained statehood before 1860. Panel (c) calculates concentration at the county level.

patenting. Acemoglu, Moscona, and Robinson (2016) show that the presence of a local post office in the early 19^{th} century is correlated with more local patents decades later, although they attribute this to state capacity rather than greater information flows. In a different context but similar vein, Hanlon, Heblich, Monte, and Schmitz (2020) find that the Uniform Penny Post, which reduced the cost of mail throughout the UK in the middle of the $19^t h$ century, led to more innovation and more collaborations between distant pairs of inventors.

A second trend occurring during the second half of the 19^{th} century is the widespread increases in higher education. Goldin and Katz (1999) refer to this period as the "formative years" of U.S. higher education. The 1862 Morrill Act, which provided land grants to states to use to fund agricultural and mechanical colleges in their states, spurred the creation of universities with a focus on practical science across the country. In most cases, these universities were not located at existing large innovation hubs, but were instead placed near the geographic center of their states to be more easily accessible to largely rural population (Andrews, 2020d). In 1890, a second Morrill Act led to a new spurt of college creation, in particular the creation of historically black colleges and universities. Andrews (2020c) shows that the establishment of a local college caused an increase in local patenting, although this increase is caused more by colleges' role in promoting population growth near colleges than the direct effects of increasing human capital. Maloney and Caicedo (2017) find that greater numbers of engineers—technically-trained and innovative professionals—in an area predict higher incomes in the future. Kantor and Whalley (2019) show that proximity to land grant colleges also facilitated the diffusion of innovations, with areas closer to colleges increasing in agricultural productivity faster than more distant areas. Notably, the benefits of proximity to a land grant college decline during the 20^{th} century, coincident with the widespread adoption of the telephone and automobile, further supporting the argument that declining transportation and communication costs led to less spatially concentrated innovation.[7]

[7] The high school movement, which brought near universal secondary education, occurred later during the 1920s and 1930s, a time in which invention was becoming more spatially concentrated (Goldin, 1998). It should not be surprising that the spread of higher education is more correlated with spatially disperse invention than is the spread of secondary education. Recent work on inventors shows that most have college degrees (e.g., Akcigit et al. (2017) on U.S. inventors in 1940, as well as Bell, Chetty, Jaravel, Petkova, and Van Reenen (2019) on modern U.S. inventors or Aghion, Akcigit, Hyytinen, and Toivanen (2018) on modern Finnish inventors). In earlier historical periods, a college degree was not especially common even for the most prolific U.S. inventors (Khan & Sokoloff, 1993).

A Pause in the Declining Concentration, 1905-1945: Around 1905, the decline in the spatial concentration of invention occurring since the end of the Civil War halted and, if anything, slightly reversed. By the early 20^{th} century, the expansion of the U.S. rail network was mostly complete, and Western Union and the Bell system had made rapid long distance communication possible. The same forces that made information easier to communicate across distance also led to a national market in invention, which in turn created a professional class of inventors (N. R. Lamoreaux & Sokoloff, 2001; N. Lamoreaux, Sokoloff, & Sutthiphisal, 2013). The increasing complexity and capital intensity of invention led to fewer independent inventors, and consequently more invention being financed and conducted by larger firms (Chandler, 1990; N. R. Lamoreaux & Sokoloff, 1996, 2005; Mowery, 1990; Nicholas, 2011). In 1880, about 95% of inventors were independent, but by 1930 more than 50% were employees of firms (Nicholas, 2010). The early 20^{th} century marked the culmination of a twenty year merger movement (N. Lamoreaux, 1985) and the dominance of large firms (Chandler, 1990). Advances in management practices also likely allowed large firms to absorb technologies at a lower cost and to better develop innovations, as, for instance, Giorcelli (2019) and Bloom, Lemos, Sadun, Scur, and Van Reenen (2014) show in other contexts. Diminished availability of local credit during the Great Depression also served to drive invention into large firms Babina, Bernstein, and Mezzanotti, 2020. Thus invention moved inside the firm at the same time that productivity became more concentrated in fewer firms.

The Postwar Decline in Concentration, 1945-1990: World War II was a watershed moment in terms of the government's involvement in research and innovative activity. Locations that received large amounts of wartime funding, some of which were not among the most innovative locations before the war, continued to be major sites for industrial production (Garin, 2019) and innovation (Gross & Sampat, 2020) after the war ended. In line with this fact, after 1945 the spatial concentration of invention entered a period of sustained decline, coinciding with the "Great Compression" of wages (Goldin & Margo, 1991).

In addition to the persistent effects of wartime spending, one likely explanation for the observed decline is the expansion of trends identified in 1866-1905. Starting in 1956, the U.S.

began construction of the Interstate Highway System, facilitating rapid automobile traffic into city centers and between cities. Agrawal, Galasso, and Oettl (2017) find that an increase in the stock of a region's highways is associated with greater regional patenting, similar to the results on railroads from more than a half century prior.[8] By facilitating movement into city centers, the Interstate Highway System, along with continued expansion of automobile ownership, also facilitated suburbanization (Baum-Snow, 2007). Berkes and Gaetani (2020) document that most innovative activity takes place not in dense urban centers, but rather in suburbs where large innovative firms tend to locate their headquarters and R&D groups. Because our concentration measures are constructed at the commuting zone level, increasing suburbanization should not affect our results (unless suburbanization changes the aggregate level of invention), but investigating changes in within-commuting zone concentration is an important topic for future work.

Access to higher education also continued to expand in the postwar era. The G.I. Bill provided funding for World War II veterans to obtain a college education, and enrollments increased commensurately. Perhaps even more important than the expansion in federal funding for college enrollments was the expansion of direct federal funding of research. In the Cold War era, the federal government became increasingly concerned that its funding for R&D was going to only a few locations, namely Harvard, MIT, and the Boston region and Stanford University and Silicon Valley. This raised political economy concerns as well as making the U.S. scientific infrastructure susceptible to Soviet nuclear attack. The federal government therefore made a conscious effort to distribute its funding across the country (O'Mara, 2005), which would decrease concentration. Kantor and Whalley (2020) document the dispersal of federal funding for National Aeronautics and Space Administration (NASA) following the launch of Sputnik on 1957. They show that because large scale NASA research

[8]It is not obvious that decreasing transportation costs should cause a decline in the concentration of invention. For instance, decreasing the costs of transportation to hub cities may lead to increased agglomeration, as documented in Duranton and Turner (2012). At the same time, Baum-Snow (2019) finds that building highways causes job losses in city centers but has little effect in the suburbs; if this causes a decrease in in urban density, it may decrease innovation in major cities (for the relationship between density and productivity, see G. A. Carlino, Chatterjee, and Hunt (2007), G. Carlino and Kerr (2015)). Overall, transportation infrastructure likely increases population in some cities while decreasing it in others, leading to an ambiguous relationship between infrastructure and population concentration (Baum-Snow, Henderson, Turner, Zhang, & Brandt, 2018).

activity in one area steals business from another local innovation policy elasticities are many times larger than aggregate innovation policy elasticities.

The Rebirth of Concentration, 1990-2016: Starting around 1990, the postwar decline in concentration abruptly halted and reversed, leading to 25 years of rapidly increasing spatial concentration of invention. This pattern is initially surprising, since the defining feature of the last quarter of a century has been the arrival of the internet which, as was the case for previous technologies, dramatically lowered the cost of communication across space and was predicted to bring about the death of distance. Several later studies found, however, that the internet was a complement and not a substitute to in-person interaction (Sinai & Waldfogel, 2004) leading to city growth (Kolko, 2012) and house price appreciation (Ahlfeldt, Koutroumpis, & Valletti, 2017). This conclusion is not uniformly accepted, with some finding that internet adoption lead to more democratization of invention and long-distance collaboration (Agrawal & Goldfarb, 2008; Forman, Goldfarb, & Greenstein, 2015; Forman & van Zeebroeck, 2012).

Regardless of the direct effect of the internet, this period also witnessed increased sorting of skills across cities. Education and universities has been a key determinant of differences in growth across cities since 1980 (E. L. Glaeser, Saiz, Burtless, & Strange, 2004; Hausman, 2020). Changes in the nature of production, consumption, and amenities are important for understanding how education affects city growth (Diamond, 2016; E. L. Glaeser, Kolko, & Saiz, 2001; Moretti, 2013). Since at least 2000 highly skilled workers have become increasingly concentrated in dense urban environments (Baum-Snow & Hartley, 2017; Couture & Handbury, 2019).

The growing importance of the service sector and knowledge work may imply local knowledge spillovers have become more important. Knowledge spillovers have recently been studied in a wide variety of settings and time periods, including advertising (Arzaghi & Henderson, 2008), manufacturing (Moretti, 2004), between scientists (Catalini, 2018; Waldinger, 2012), from universities (Kantor & Whalley, 2014, 2019), in high tech clusters (Moretti, 2019), from defense spending (Moretti, Steinwender, & Van Reenen, 2019), in call centers (Sandvik, Saouma, Seegert, & Stanton, 2020), from R&D labs (Buzard, Carlino, Hunt, Carr, & Smith, 2019), from the SBIR program (Myers & Lanahan, 2020), in informal settings like bars (Andrews, 2020a), and across patents (Ganguli, Lin, & Reynolds, 2020; Jaffe et al., 1993). While these studies all show that local knowledge spillovers are an important phenomenon, there is less consensus on that they have become increasingly important in recent decades; see Clancy (2020) for an overview of this debate with a focus on studies that find declining importance of local knowledge spillovers. What is clear is that quantifying how spillovers have changed over long periods of time remains an important avenue for future work.

Finally, since the 1980s the high costs of expanding the housing supply in places like San Francisco and New York, due to either geographic constraints or zoning regulations, have led to "superstar cities" (Gyourko, Mayer, & Sinai, 2013) with very high rents, which may in turn have driven out workers in non-innovation sectors that have lower average incomes. Housing prices have risen especially dramatically in cities with large knowledge sectors (Moretti, 2013) and small business employment (Adelino, Schoar, & Severino, 2015).

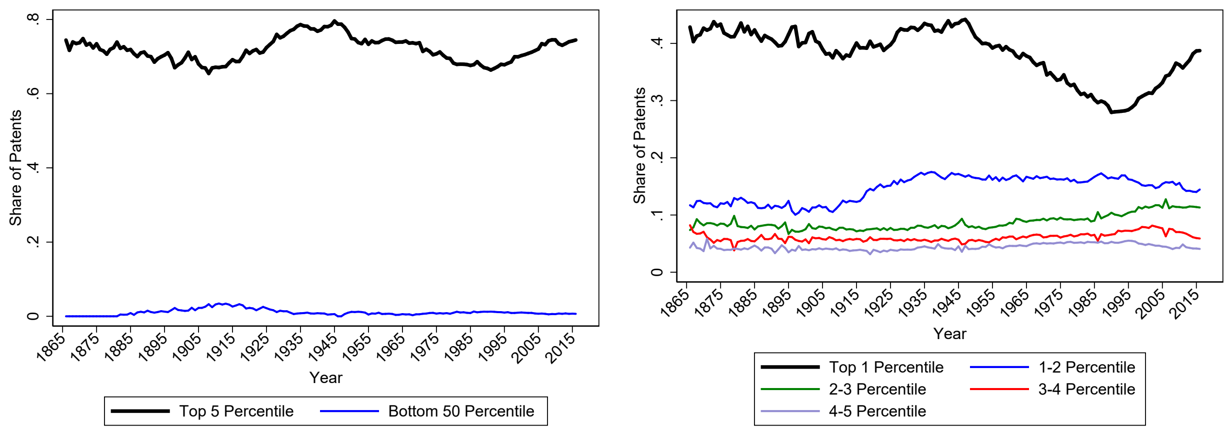
4 Elite Innovation Places

As an alternative way to visualize the spatial concentration of invention, in Figure 2 we look at the share of patents from commuting zones in different parts of the patenting distribution through time. In panel (a), we plot the share of patents from the top 5% of commuting zones by patenting in each year along with the bottom 50%. The share of U.S. patents from the the top 5% largely mirrors the national trends in spatial concentration in Figure 1, with the top percentiles accounting for a larger share when concentration is high and vice versa. The share of patents in the bottom 50% of the distribution move far less and, in all years, account for only a trivial share of patents.[9]

[9]Not only have the commuting zones in the bottom half of the patenting distribution failed to gain ground on the top commuting zones in a relative sense, but even in absolute terms they have seen little increase in patenting. Since 1945, the share of commuting zones that have zero patents in a given year has hovered around 15-20%, in spite of a large nationwide increase in the number of patents. In fact, the share

In panel (b) we further break down patenting by the top commuting zones. The trends for the top 1% share after 1945 mirror national trends in spatial concentration very closely. But even in the trough years around 1990, the top 1% of commuting zones account for nearly 30% of all U.S. patents, and in most years they account for 40-45%. The share of invention going to the 2nd to 5th percentiles is largely flat. Overall, trends in national innovation spatial concentration appear to be driven by a few elite innovation hubs.

Figure 2: Share of Patents, by Percentile



Notes: The share of aggregate U.S. patents coming from select sets of commuting zones from 1866 to 2016. In panel (a), the black line shows the share of aggregate U.S. patents coming from the top 5% of commuting zones by yearly patenting and the blue line shows the share from the bottom 50% of commuting zones by yearly patenting. Panel (b) decomposes patenting by the top 5% of commuting zones by yearly patenting, with black line showing patenting by the top 1% of yearly patenting commuting zones, the blue line the 2nd percentile, the green line the 3rd percentile, the red line the 4th percentile, and the purple line the 5th percentile.

Have today's elite innovation hubs always been highly innovative? How much churn is there in the identities of the elite innovation hubs? Many policymakers expect the location of innovation leadership to be highly persistent. If there are increasing returns and cumulative innovation effects at the regional level, then early leads in innovation would be likely to compound, producing persistence. Recent work has shown that local technology shocks have persistent effects on regional development (Hanlon, 2017, 2019) and local shocks can affect technology adoption (Juhász, 2018). Early investments in innovative capabilities may

of commuting zones with zero patents in a given year is larger today than it was in 1915.

also take time pay off. For instance, Senator Daniel Patrick Moynihan was said to have quipped "If you want to build a world class city, build a great university and wait 200 years". At the same time, innovations can diffuse broadly even over relatively short periods of time (Griliches, 1957). As knowledge about once-new technologies becomes commonplace, geographic proximity to innovators may be less important, as Kantor and Whalley (2019) show in the context of proximity to agricultural research. Moreover, many of the events that led to the success of today's elite innovation hubs appear to have little to do with past innovation success, such as William Shockley's and Bill Gates's decisions to locate their firms in Silicon Valley and Seattle, respectively, to be closer to family.

To investigate persistence, in Figure 3 we examine how the correlations between the share of national patents in a commuting zone differs over long time periods. We split our time period in half and plot the correlations between the share of total national patents from each commuting zone from 1866 to 1941 in panel (a) and from 1941 to 2016 in panel (b).[10] We see some evidence of persistence, though for both sets of years the regression line is below the 45 degree line and the data cloud is quite scattered. Persistence appears to be dropping — persistence over the last 75 years is significantly less than over the previous 75 years.[11]

The top 1% of commuting zones by patents in 1866 and 2016 are marked in Figure 3. The top patenting commuting zones in 1866 tended to be the country's largest cities, with New York, Chicago, and Philadelphia ranking in the top 1%. The northeast was dominant, with Boston-Cambridge, MA; Newark, NJ; and Bridgeport, CT, also in the top 1% (the latter two of which are also close to New York). Of these top six commuting zones in 1866, four were still in the top five in 1940, and all were in the top seven.

The top commuting zones in 2016 are San Jose, CA, which includes Santa Clara, Palo Alto, and most of Silicon Valley; San Francisco, CA, which includes Oakland and Berkeley; Los Angeles, CA; Spokane, WA; San Diego, CA; Cambridge and Boston, MA; and Chicago,

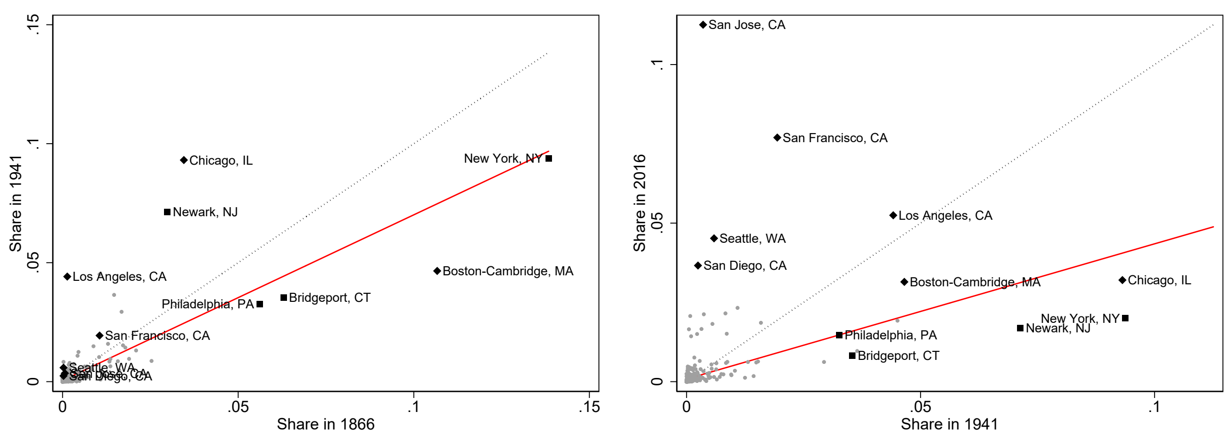
[10]We obtain similar correlation coefficients when using alternative cutoff dates, for instance by splitting the sample at the last full pre-World War II year in 1940 or at the start of the postwar decline in concentration in 1945 or 1946.

[11]While we plot share-share correlations, rank-rank correlations similarly reveal significant but modest correlations over time and an even starker decline in the correlation coefficient from 1866-1941 to 1941-2016.

IL. In 2016, the West Coast, and especially Silicon Valley, is nearly as dominant as the northeast was in 1866. As Forman, Goldfarb, and Greenstein (2016) show, the recent dominance of Silicon Valley in patenting reflects more than simply an early lead in information technology patents, but instead is apparent across multiple patent classes. Of the current top patenting locations on the West Coast, all accounted for a negligible share of national patents just after the Civil War, and only Los Angeles and, to a lesser extent, San Francisco, accounted for more than a non-negligible share in 1941. Thus the rise of the West Coast, especially in San Jose and San Diego, is a post-war phenomenon, reflecting the fact that there has been more churn in the identities of the leading innovative locations over the last 75 years than in the previous 75 years.

Figure 3: Share-Share Correlations

(a) 1866 to 1941 (b) 1941 to 2016



$$SharePat_{1941} = \underset{(0.000)}{0.001^{*}} + \underset{(0.024)}{0.696^{***}} SharePat_{1866}.$$

$$SharePat_{2016} = \underset{(0.000)}{0.001^{***}} + \underset{(0.032)}{0.426^{***}} SharePat_{1941}.$$

Notes: Scatter plots of the correlation between the share of aggregate U.S. patents from each commuting zone at two different points in time. Panel a plots the share of patents from commuting zones in 1866 and 1940, and panel b plots 1940 and 2016. In both panels, the gray dashed line is the 45-degree line and the red solid line is the line of best fit. Equations for the line of best fit are listed under each panel. The top 1% of commuting zones by patents in 1866 and 2016 are labeled and marked with black squares and diamonds, respectively. Boston-Cambridge, MA, and Chicago, IL, were in the top 1% of commuting zones in both 1866 and 2016.

The fact that there has been substantial turnover in the identities of top inventing places suggests that the location of invention is not fixed by geography or historical accident, and that policy may have a role to play in promoting local or regional innovation. One piece of the puzzle appears to be allowing for high labor mobility among technological workers as in California (Marx, Singh, & Fleming, 2015). Another piece appears to be attracting and retaining highly innovative knowledge elites (Akcigit, Caicedo, Miguelez, Stantcheva, & Sterzi, 2018; Iaria, Schwarz, & Waldinger, 2018). Upper tail human capital has been related to regional development in numerous contexts, including in the United States (Maloney & Caicedo, 2017), England (Mokyr, 2009), France (Squicciarini & Voigtländer, 2015), and Germany (Dittmar & Meisenzahl, 2020). While there is strong evidence that the presence of these individuals is vital for regional innovation and economic growth, policymakers face the challenge of deciding how to attract and keep them, especially since innovators tend to be geographically mobile and sensitive to local policies such as tax rates (Akcigit, Baslandze, & Stantcheva, 2016; Moretti & Wilson, 2014, 2017). Few papers formally model the presence of heterogeneous abilities in cities, and those that do (Berens, Duranton, & Robert-Nicoud, 2014; Davis & Dingel, 2019) have not explicitly examined innovation. In contrast to our findings, in a study of the geography of creative talent in Europe from 1500-1900, Serafinelli and Tabellini (2020) find that there was little change in the concentration of creativity and that, if anything, persistence is increasing over time. Understanding of the role knowledge elites play in shaping innovation hubs, and how their role changes in different contexts, is a promising direction for future work.

We see a large role for historical studies with long time periods to understand the limits of regional persistence, such as Lin (2012) on population resilience and Berkes, Gaetani, and Mestieri (2020), E. L. Glaeser, Kallal, Scheinkman, and Schleifer (1992), Jacobs (1969) on technological diversity and city growth. Careful case studies such as the E. L. Glaeser (2005a) study of Boston and Easterly, Freschi, and Pennings (2016), E. L. Glaeser (2005b) studies of New York delve deeply into how cities' real economies have confronted long term structural changes to their economies. There is much more work to be done here as long-term data on innovation and other regional outcomes become increasingly available. Even with detailed data, the presence of non-local spillovers in the innovation process makes drawing conclusions about how the geography of innovation and economic growth are linked difficult without a theoretical model. Kantor and Whalley (2020) is an example that combines both approaches.

5 Conclusion

The existence and even the magnitude of agglomeration economies have now become well established in the urban economics literature. We know far less about how these forces have changed. Our analysis of 150 years of patent data shows that the geography of innovation has changed substantially over time. While we have suggested factors that may account for these changing patterns and why they matter, much more work is needed. There is plenty to be learned, and with data constraints becoming less and less binding, plenty of opportunities to learn. We are excited to see what the next several years bring in this research agenda.

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