DETERMINANTS OF GROWTH AND PROSPERITY IN U.S. METROPOLITAN AREAS

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P³ PRODUCTIVITY AND PROSPERITY PROJECT

ASU W. P. CAREY SCHOOL of BUSINESS
ARIZONA STATE UNIVERSITY

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SUMMARY

Urban economists have been busy trying to understand the forces at work behind the new and varied growth experiences of U.S. metropolitan areas over the past three decades. Rapid population growth in the Las Vegas, Phoenix, Dallas, and Houston metro areas attests to the continued pull of the Sunbelt. A more recent phenomenon is the rise of superstar metros such as Seattle, Boston, and San Francisco with economies that are heavily involved in innovation and the production of high-technology goods. After a century of regional economic convergence, human capital is beginning to concentrate in selected metro areas, creating a divergence in average real (cost-of-living-adjusted) earnings and income across U.S. metro areas. At the heart of this divergence appears to be a re-emergence of the forces of agglomeration, where spatial concentration of economic activity provides greater efficiencies in innovation and a competitive advantage in industries competing in the global marketplace.

This report provides a review of the literature in urban economics and economic geography on the determinants of population growth and prosperity in U.S. metro areas, focusing on papers published since 2000. Since the data in many of these papers end around 2000, this report will also provide an empirical update using data on population growth from 2000 to 2018 and data for 2018 on real earnings per worker and real per capita income. The newly estimated models are used to assess the economic performance of selected metro areas, including Phoenix and Tucson.

The major conclusions of this report are summarized below:

- Based on his extensive research, Ed Glaeser has concluded that no single variable can better predict population growth in U.S. metro areas from 1950 to 2000 than climate, particularly the warmth of winters as measured by mean January temperature. The analysis presented in this report confirms Glaeser's conclusion for the period from 2000 to 2018. Mean January temperature is still the single-most significant variable in explaining recent patterns of U.S. urban population growth. It remains unclear whether the continued pull of the Sunbelt is driven by household preferences for living in warm climates or by a lower relative cost of producing in this region of the country.

- Ed Glaeser, Enrico Moretti, and others have argued that metro-area differences in the degree to which housing supply responds to demand (elasticity), whether due to geographic limitations or housing policy, have had a profound effect on the pattern of U.S. urban growth. Responsiveness of new home construction to increases in housing demand determines whether urban success reveals itself in the form of a larger population or higher housing prices. Using estimates from Saiz (2010) of elasticities of housing supply for individual metro areas, this report finds local conditions of housing supply to be an important determinant of urban population growth over the 2000-to-2018 period. As others have found, explicit consideration of housing supply helps to explain the underperformance (in terms of population growth) of coastal metro areas such as San Francisco, Boston, and Miami and the overperformance of inland areas such as Atlanta, Dallas, and Houston.

- Initial levels of human capital in an area, as typically measured by the share of the population with a bachelor's degree, have been shown in numerous studies to be a

significant predictor of subsequent population growth in the area. This finding is confirmed for the period from 2000 through 2018 for each of two alternative measures of human capital: the share of the adult population with at least a bachelor's degree and the percent of employment in STEM (science, engineering, technology, and math) occupations. As a predictor of metro area population growth, educational attainment is somewhat stronger than STEM intensity of employment.

- A complete model of urban population growth, which includes climate, responsiveness of housing supply, and human capital, is estimated for the 2000-through-2018 period. The estimated model is used to assess the contributions of these factors to population growth in the Phoenix and Tucson metro areas. Population growth in Metro Phoenix over the period from 2000 to 2018 was 23 percentage points faster than the average of 83 metro areas with a population of more than 250,000 in 2000 for which housing supply elasticity has been estimated. Seventeen percentage points of this difference can be attributed to climate. But after adjusting for the moderately growth-limiting effects of housing supply and educational attainment, there are an additional 9 percentage points of growth that are left unexplained. Population growth in Metro Las Vegas, too, was substantially faster than what would be expected from the model. There may be some overlap in the stories behind the unexplained growth in these two metro areas.

  Population growth in Metro Tucson over the period from 2000 to 2018 was similar to the average of the 83 metro areas, despite the fact that Metro Tucson has January temperatures that should have been worth an additional 15 percentage points of growth. Restrictive housing supply can explain 7 percentage points of that growth shortfall. But there are other factors not identified in the model that reduced population growth by another 7 percentage points.

- Traditional urban theory suggests that real earnings per worker should vary across metro areas with differences in levels of human capital and amenities (nonmonetary features of an area that make it more attractive to residents, such as natural beauty, climate, and culture). An empirical model was estimated in which real earnings per worker in 2018 was explained by contemporaneous measures of metro area educational attainment and STEM share of employment, and, as an amenity variable, mean January temperature. The results indicate that the STEM intensity of employment is far and away the most important determinant of earnings per worker. In one set of regressions, the estimated coefficients for the STEM share imply that the difference in STEM share of employment between Metro Austin (at 9.0 percent) and Metro Phoenix (at 5.8 percent) is enough to make average annual compensation per worker in Austin $4,500 to $9,200 higher than it is in Phoenix.

  The coefficients estimated for mean January temperature are negative and generally significant. These results are consistent with the view that warm winters are an amenity for which households are willing to sacrifice real earnings. In one set of regressions, the size of the estimated climate coefficients are such that an increase in mean January temperature of 31 degrees, equivalent to what would be experienced in moving from Chicago to Phoenix, is worth between $4,200 and $5,600 per worker.

- This report also provides a regression analysis of determinants of metro-area real per capita personal income in 2018. Explanatory variables include some of the variables used to explain earnings per worker (human capital variables and climate), measures of the employment-to-population ratio, and, as an indicator of the importance of nonearnings income, the share of the metro population that is 65 years and older. When analyzing per capita income rather than earnings per worker, the dominant human capital variable is the share of the population with at least a bachelor's degree, not the STEM share of employment. Much of the significance of the educational attainment variable derives from the fact that metro areas with a highly educated population also have high employment-to-population ratios. The higher the educational attainment, the larger the share of the population employed as wage and salary workers and the larger the share that is self-employed.

  The estimated model provides a method of accounting for differences in real per capita personal income between Metro Phoenix, Metro Tucson, and the average 82 metro areas (excluding San Jose). Metro Phoenix's per capita income is $6,900 below the average. Warm winters can explain $1,500 of that gap, and a low employment-to-population ratio can explain another $2,300. But there is $2,900 that cannot be explained by the variables in the model. Metro Tucson's per capita income is $7,500 below the average of the 82 metro areas. Warm winters explain $1,300 of that gap, and a low employment-to-population ratio contributes another $5,500. However, a relatively large elderly population should make the Tucson area's per capita income $1,400 higher than the national average. This leaves an overall shortfall of $2,300 that is left unexplained.

- Contributing to the recent divergence of productivity and per capita income across U.S. metro areas and regions has been an increasing concentration of human capital. Ed Glaeser, Enrico Moretti, and others have shown for large samples of metro areas that there is a positive correlation between the initial share of the adult population that has a university degree and the size of the increase in that share over the subsequent decade. This relationship is confirmed for the period since 2000 for two measures of human capital: the share of the adult population with a bachelor's degree and the STEM share of employment.

  Over the 2005-to-2018 period, Metro Phoenix registered an increase in the bachelor's degree share of 4.2 percentage points, which is about what would be expected given its initial share. Metro Tucson, on the other hand, registered a gain in share of only 2.3 percentage points, which was below expectations.

  Over the period from 2001 to 2019, Metro Phoenix experienced a gain in STEM share of employment of 0.30 percentage points, which was 0.35 points below expectations. Metro Tucson had an increase in STEM share of 0.46 percentage points, but this was 0.23 percentage points below what would be expected on the basis of its initial STEM share.

POPULATION GROWTH, CLIMATE. AND HOUSING SUPPLY

The Rise of the Sunbelt

From 1900 to 1970, the share of the U.S. population living in the Western region of the country grew steadily from 5 percent to 17 percent, slowly drawing down the shares of the population living in the Midwest and the Northeast, particularly the Midwest (see Chart 1). The share of the nation's population living in the South scarcely changed. Then from 1970 to 1990, the rate of decline in the population shares of the Midwest and Northeast accelerated, with each region losing roughly 4 percentage points of the national population; the population shares of the West and the South increased rapidly, by 4 percentage points in the West and by 3½ percentage points in the South. These regional patterns of shifts in the population have continued since 1990, but at a somewhat slower pace, especially in the West. From 1990 to 2018, the South's share of the U.S. population increased by 3¾ percentage points, while the West region's share increased by 2½ percentage points.

Regional shifts in the U.S. population since 1970 are commonly attributed to a desire on the part of households to live in parts of the country with more days of sunshine and warmer winters and to economic decisions of companies to relocate or abandon heavy manufacturing industries historically located at sites in the Northeast and Upper Midwest, as necessitated by domestic and international competition.

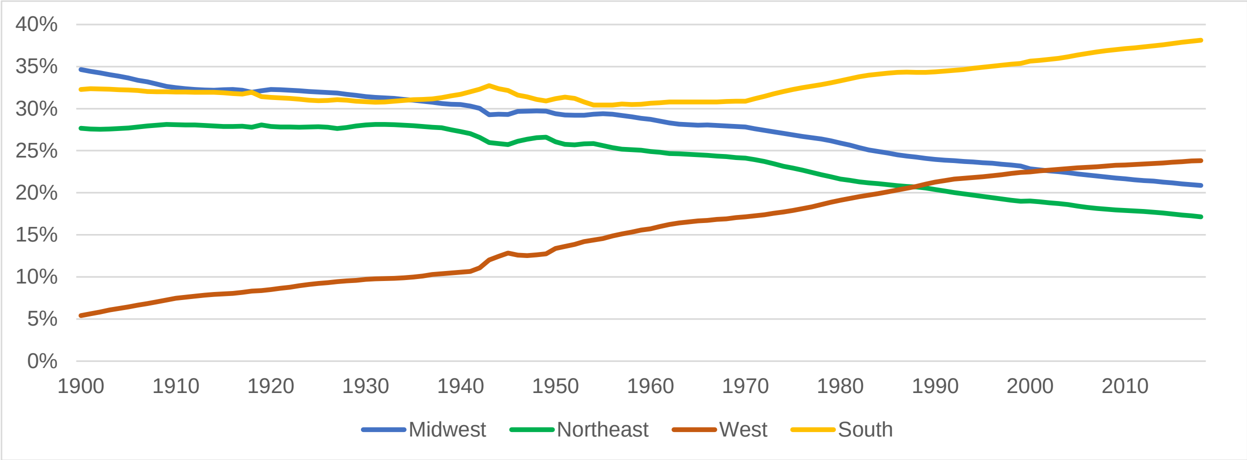
Many economists have weighed in on the underlying factors behind the movement of people and jobs to the West and South.[1] One group of explanations related to amenities[2] focuses on the possibility that Sunbelt states have become more attractive places to live. People have generally preferred to live in places with mild winters. The advent and increasing efficiency of air conditioning made it possible to enjoy warm winters without the intense heat and discomfort of the summer. In the South, public investments after World War II provided for cleaner drinking water and a lower incidence of disease. In the West and the South, a lack of fixed urban capital made it easier to design cities around the automobile and serve a strong demand for suburban living. As hypothesized by Glaeser and Shapiro (2003), the correlation between climate and population growth may be general evidence of the growing importance of consumers relative to producers in location decisions.

Another group of explanations related to productivity argues that the rapid growth of Sunbelt states, particularly those in the South, has been driven by a decrease in the relative cost of producing in this region of the country. The air conditioner makes summers more comfortable not only for households but for factory workers as well. The dramatic decline in the costs of transporting goods that occurred during the 20th century has made it less important to be near natural resources and has reduced the advantage northern areas had from proximity to waterways and dense railroad networks. It is also argued that political reforms and public policy in the South enhanced the productivity of the region. The Civil War had eliminated much of the

[1] See Glaeser and Tobio (2008) for references to the papers of authors who have contributed to the debate on the reasons for the growth of the Sunbelt in general, and the economic resurgence of the South, in particular.

[2] Amenities are nonmonetary features of an area that make it more attractive to residents, such as natural beauty, climate, and culture.

CHART 1
SHARE OF U.S. POPULATION BY CENSUS REGION



Source: U.S. Department of Commerce, Census Bureau.

influence of special interest groups in the South and allowed for free entry of new business into the region. State and local governments became less focused on maintaining white supremacy and more interested in subsidizing industry. The pro-business culture of the South was also aided by low unionism and right-to-work laws.

Glaeser and Tobio (2008) used the Rosen-Roback model of spatial equilibrium[3] and data on U.S. metro area growth in population, income, and house prices to disentangle the relative influence of amenities, productivity, and a third factor — the elasticity of housing supply[4] — on the growth of the South from 1950 to 2000. The authors found that population growth in the South from 1950 to 1980 was driven primarily by productivity gains. During this period, population increased, house prices increased, and nominal incomes increased faster than house prices. These observations are consistent with the productivity explanation for growth but not the amenities or housing supply explanations. Since 1980, housing supply has become as important as productivity in explaining population growth in the South. Housing prices have increased more slowly than in the rest of the nation and more slowly than nominal incomes. This is the opposite of what one would expect if growth had been amenity driven but consistent with the housing supply explanation of Southern population growth. Overall, the authors reached the conclusion that growth in the South has had very little to do with sun-related amenities. Indeed, the steady relative growth in real[5] Southern incomes, after controlling for education, suggests that marginal residents are requiring higher compensation to live in the South.

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[3] In a spatial equilibrium, households cannot increase utility (the satisfaction received after utilization of an item) by changing location. This implies that differences in money earnings across locations must be offset by differences in cost of living (e.g., housing prices) or amenity levels.
[4] The elasticity of housing supply measures the percentage change in the quantity of new housing that is produced in response to a one-percent increase in the price of housing. The larger is the elasticity, the larger is the effect of an increase in housing demand on new home construction and the smaller the effect on housing prices.
[5] "Real" in this context refers to a dollar value adjusted for the regional cost of living, using the regional price parity estimates of the U.S. Department of Commerce, Bureau of Economic Analysis.

No Better Predictor Than January Temperature

Given the regional pattern of U.S. population growth after World War II, it is not surprising that climate variables are highly correlated with urban population growth. Ed Glaeser and his coauthors (e.g., see Glaeser and Shapiro 2003, and Glaeser and Tobio 2008) have evaluated the statistical significance of alternative climate variables as explanatory variables for U.S. metro area population growth: warmth in the winter months (as measured by mean January temperature), warmth in the summer months (as measured by mean July temperature), and average annual precipitation. There is evidence in some decades of people moving to areas with dry climates (low precipitation) and warm summers (especially after 1990). But what is most consistent with the facts on urban population growth since 1950 is that people are most attracted to areas with warm winters. As Glaeser is fond of saying, "no variable can better predict city growth over the past 50 years than January temperature" (Glaeser and Gottlieb 2009, p. 984). Mean January temperature is not only the single most-significant predictor of urban population growth among climate variables, it is more significant than any economic variable including metro-level educational attainment, population density, availability of public transportation, and historical importance of manufacturing in the local economy.

Glaeser's analysis of the relationship between January temperature and urban population growth covers the postwar period up through 2000. Table 1 and Chart 2 provide an update to this analysis for 25 large metro areas. Chart 3 examines the correlation between urban population growth and January temperature for a larger sample of 171 metro areas with a population of at least 250,000 in 2000.

Table 1 shows for each of 25 selected large metro areas, the percentage change in population (as measured by the change in natural logarithms[6]) over the 1980-to-2018 period together with the mean January temperature of each metro area over the 1981-to-2010 period. The observations are ordered by mean January temperature. There is a clear positive correlation between urban population growth and January temperature. The mean logarithmic growth for metro areas with a mean January temperature of at least 40 degrees is 0.798 as compared with a mean growth rate of 0.220 for metro areas with a mean January temperature below 40 degrees.

A scatter plot of the data is shown in Chart 2 along with the least-squares linear regression line.[7] Climate alone can explain 33 percent of the variation in the population growth of these metro areas. According to the regression, an increase of 10 degrees in January temperature is associated with an increase in population growth of 18 percent (as measured in log points).

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[6] When a variable changes by a large amount, as is the case with population growth over a decade or more, percentage changes are often calculated as the change in the natural logarithm of the variable. The result is similar to one obtained by taking the absolute change and dividing it by the average value of the variable rather than by its initial value.

[7] Regression analysis is a statistical method used to estimate or predict the unknown values of one variable from the known values of other variables. The variable being predicted is known as the dependent variable. The variables which are used to predict the dependent variable are called the independent or explanatory variables. A least-squares regression method is a form of regression analysis which establishes the relationship between the dependent and independent variables along with a linear line referred to as the "line of best fit."

Chart 3 provides a scatter plot of population growth over the period from 2000 to 2018 and mean January temperature for the larger sample of 171 metro areas. In this sample, January temperature is again statistically significant as a predictor of population growth and serves to explain 21 percent of the variation in metro area population growth. According to the regression, each additional 10 degrees of January temperature is associated with a 5-percentage-point increase in population growth over this period.

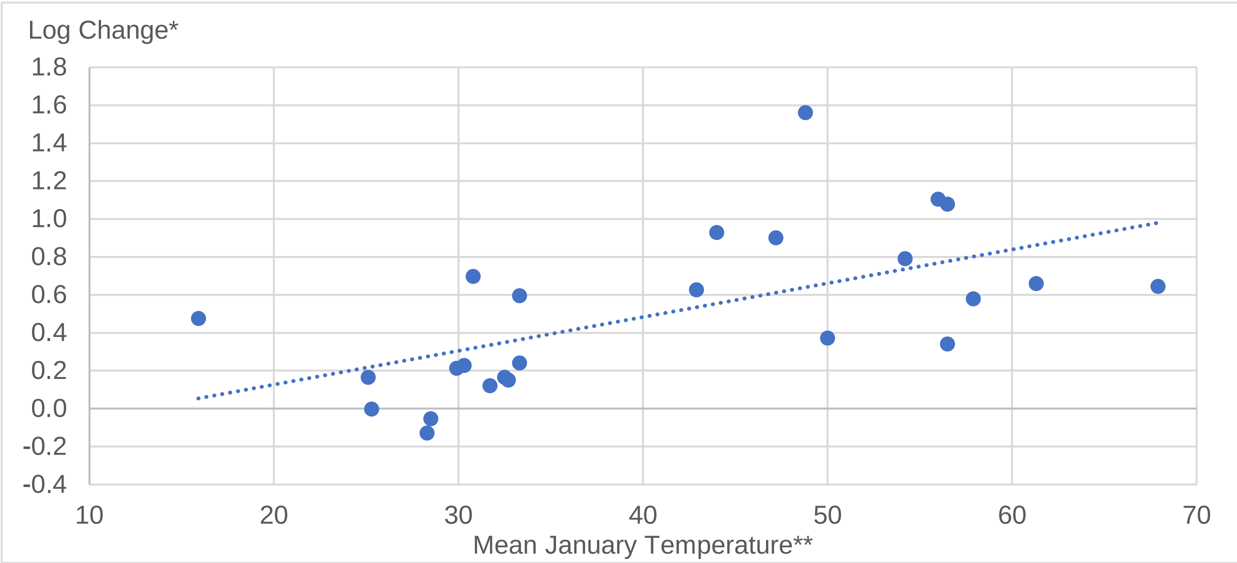
TABLE 1
POPULATION GROWTH IN 25 SELECTED LARGE METROPOLITAN AREAS

	Population in 2018	Change in Population, 1980 to 2018	Log Change in Population, 1980 to 2018*	January Temper-ature**
Miami-Fort Lauderdale-Pompano Beach, FL	6,198,782	2,943,846	0.644	67.9
Tampa-St. Petersburg-Clearwater, FL	3,142,663	1,515,688	0.658	61.3
San Diego-Chula Vista-Carlsbad, CA	3,343,364	1,467,744	0.578	57.9
Los Angeles-Long Beach-Anaheim, CA	13,291,486	3,836,875	0.341	56.5
Riverside-San Bernardino-Ontario, CA	4,622,361	3,049,932	1.078	56.5
Phoenix-Mesa-Chandler, AZ	4,857,962	3,245,780	1.103	56.0
Houston-The Woodlands-Sugar Land, TX	6,997,384	3,824,525	0.791	54.2
San Francisco-Oakland-Berkeley, CA	4,729,484	1,468,554	0.372	50.0
Las Vegas-Henderson-Paradise, NV	2,231,647	1,762,462	1.559	48.8
Dallas-Fort Worth-Arlington, TX	7,470,158	4,434,675	0.901	47.2
Atlanta-Sandy Springs-Alpharetta, GA	5,949,951	3,597,796	0.928	44.0
Seattle-Tacoma-Bellevue, WA	3,939,363	1,833,539	0.626	42.9
Baltimore-Columbia-Towson, MD	2,802,789	599,404	0.241	33.3
Washington-Arlington-Alexandria, DC-VA-MD-WV	6,263,245	2,810,031	0.595	33.3
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	6,096,372	852,354	0.151	32.7
New York-Newark-Jersey City, NY-NJ-PA	19,303,808	2,925,915	0.164	32.5
St. Louis, MO-IL	2,805,465	318,476	0.120	31.7
Denver-Aurora-Lakewood, CO	2,932,415	1,471,455	0.697	30.8
Cincinnati, OH-KY-IN	2,212,945	450,234	0.227	30.3
Boston-Cambridge-Newton, MA-NH	4,875,390	929,276	0.211	29.9
Cleveland-Elyria, OH	2,057,009	-115,429	-0.055	28.5
Pittsburgh, PA	2,324,743	-321,663	-0.130	28.3
Detroit-Warren-Dearborn, MI	4,326,442	-13,336	-0.003	25.3
Chicago-Naperville-Elgin, IL-IN-WI	9,498,716	1,445,773	0.165	25.1
Minneapolis-St. Paul-Bloomington, MN-WI	3,614,162	1,365,718	0.475	15.9

* Change in the natural logarithm.
** Mean (average of high and low) January temperature in Fahrenheit degrees over the period from 1981 to 2010.

Sources: U.S. Department of Commerce, Census Bureau (population) and U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Environmental Information (temperature).

CHART 2
POPULATION CHANGE BETWEEN 1980 AND 2018 AND JANUARY TEMPERATURE IN 25 LARGE METROPOLITAN AREAS



* The change in population, as measured by natural logarithms, between 1980 and 2018.
** Mean (average of high and low) January temperature in Fahrenheit degrees from 1981 to 2010.

Sources: U.S. Department of Commerce, Census Bureau (population) and U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Environmental Information (temperature).

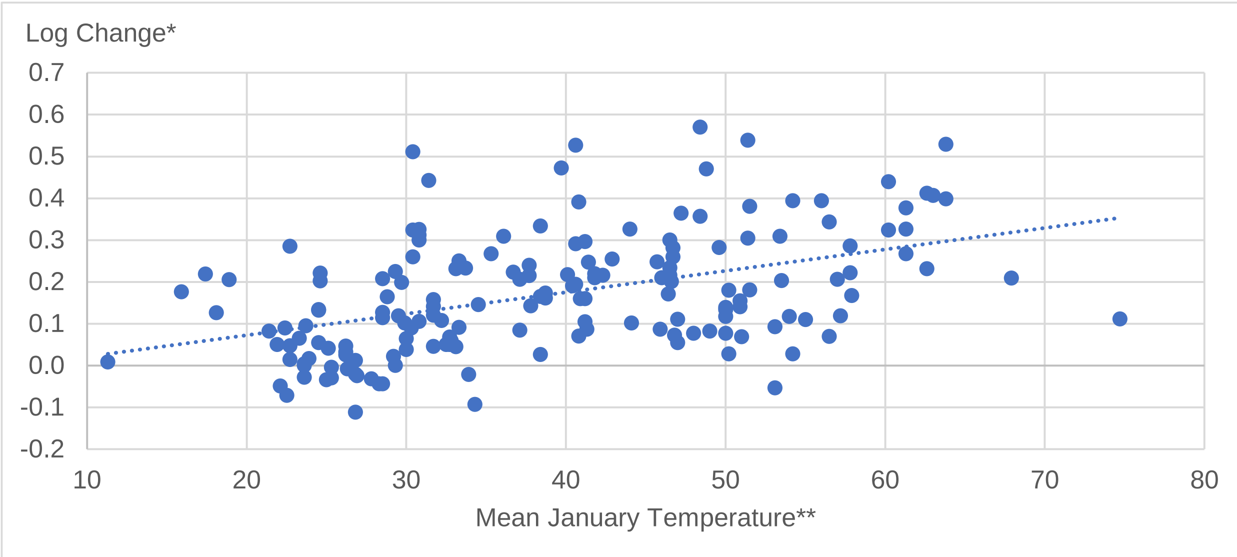
The climate coefficient estimated for the sample of 171 metro areas over the 2000-to-2018 period is considerably smaller than one estimated for the same sample using population growth over the period from 1980 to 2000. Some decline in the sensitivity of urban population growth to January temperature would be expected given that U.S. population growth slowed from 1.1 percent per year between 1980 and 2000 to 0.8 percent per year between 2000 and 2018. A decline in the climate coefficient is also consistent with data showing a general decrease in U.S. labor mobility since 2000.

The Importance of Housing Supply

In their review of the use of the Rosen-Roback spatial equilibrium model in urban economics, Glaeser and Gottlieb (2009) emphasized that when thinking about metro areas, population, housing prices, and incomes must be considered together. Housing supply elasticity will determine whether urban success reveals itself in the form of population growth or increases in housing prices and nominal incomes. Because of differences in both local geography and land-use policies, urban areas differ greatly in the extent to which housing supply can increase in response to an increase in housing demand.

In a *Journal of Economic Perspectives* review of the importance of housing supply, Glaeser and Gyourko (2018) argued that restrictions on housing supply between the 1960s and 1990s, especially in high-growth coastal areas, raised the price of housing well above production costs. Inelasticity in housing supply had a significant effect on the distribution of wealth and the pattern

CHART 3
POPULATION CHANGE BETWEEN 2000 AND 2018 AND JANUARY TEMPERATURE IN 171 METROPOLITAN AREAS



Note: The sample consists of those metro areas with a population of at least 250,000 in 2000.

* The change in population, as measured by natural logarithms, between 2000 and 2018.
** Mean (average of high and low) January temperature in Fahrenheit degrees from 1981 to 2010.

Sources: U.S. Department of Commerce, Census Bureau (population) and U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Environmental Information (temperature).

of urban growth in these areas, which took the form of higher housing prices rather than more people and workers. The authors focused their policy comments on the regulatory barriers to home construction but acknowledged that there are important natural differences in housing supply elasticity related to geography — the flat Midwest and South versus coastal and mountainous areas where developable land is limited by the sea and topography.

Hsieh and Moretti (2019) argued that strict zoning laws in U.S. urban areas with high productivity growth, such as the New York and the San Francisco Bay areas, have heavily distorted housing prices in those areas and created a significant spatial misallocation of labor in the country. Using the Rosen-Roback model and data from 220 U.S. metro areas over the 1964-to-2009 period, the authors attempted to quantify the efficiency costs of housing restrictions in selected large U.S. metro areas. In a counterfactual calculation, the authors found that if land-use restrictions in the New York, San Jose, and San Francisco areas were relaxed to the level of the median U.S. city, U.S. gross domestic product in 2009 would have been 3.7 percent higher and average earnings in the country would have been $3,685 higher.

In view of the findings of urban economists on the importance of the elasticity of housing supply for urban growth, it should come as no surprise that in the earlier analysis of population growth in 25 large U.S. metro areas (Chart 2), areas with population growth that was below what would have been predicted on the basis of climate included major coastal metro areas in California (Los Angeles, San Diego, and San Francisco) and coastal areas in the East (Boston, Miami, and New York). These are all urban areas in which housing supply is limited by geography and/or land-use restrictions. In contrast, metro areas like Atlanta, Dallas, Houston, and Phoenix — areas with geography and housing policies that are more conducive to an expansion of the housing stock — all experienced population growth well above the rates predicted by climate.

Saiz (2010) developed estimates of the price elasticity of housing supply for major metro areas that account for the effects of both geographical and regulatory constraints on new home construction. Saiz used satellite data on terrain elevation and surrounding bodies of water to estimate the amount of developable land in a metro area. Strictness of land-use regulations was assessed using the Wharton Residential Urban Land Regulation Index.[8] The two sets of information were combined to produce estimates of housing supply elasticities.

Table 2 shows information on population growth over the 2000-to-2018 period, per capita personal income in 2018 adjusted for the cost of living, mean January temperature, housing supply elasticities, educational attainment, and the STEM (science, engineering, technology, and math) share of employment, as measured by occupation, for 83 metro areas with a population of at least 250,000 in 2000 and for which estimates of housing supply elasticity are available from Saiz.

Table 3 shows the results of three alternative regressions using this sample of data, starting with a simple regression with only January temperature as an independent variable and then adding housing supply elasticity. Climate alone accounts for 29 percent of the variation in metro area population growth. According to the climate coefficient estimated in regression 1, a 10-degree increase in January temperature is associated with a 6.8 percentage-point increase in the growth of population between 2000 and 2018. The simple addition of housing supply elasticity to this model (regression 2) modestly improves the adjusted R-squared[9] and slightly increases the size of the climate coefficient. The variable measuring elasticity of housing supply is itself statistically significant at the 95 percent level of confidence.

A more significant improvement in the explanatory power of the regression occurs when housing supply elasticity is interacted with (multiplied by) climate (see regression 3). Theoretically, the effects of climate on population growth should go to zero as the elasticity of housing supply goes to zero. The functional form used in regression 3 accomplishes this. The adjusted R-squared increases to 0.41 and all independent variables are highly significant. When evaluated using the mean housing supply elasticity of 1.93, regression 3 indicates that a 10-degree increase in January temperature is associated with a 9.3 percentage-point increase in population growth, rather than the 6.8 percentage-point increase suggested by regression 1.

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[8] The Wharton Residential Urban Land Regulation Index is constructed to capture the stringency of residential growth controls. See Joseph Gyourko, Albert Saiz, and Anita Summers. 2008. “A New Measure of the Local Regulatory Environment for Housing Markets: The Wharton Residential Land Use Regulatory Index,” *Urban Studies* 45:3, 693–729.

[9] R-squared is a statistical measure that ranges from zero to one. It represents the proportion of the variance in a dependent variable that is explained by an independent variable or variables in a regression model.

TABLE 2
DATA FOR 83 METROPOLITAN AREAS

	Log Change, Popula-tion, 2000-18	Real Per Capita Personal Income, 2018	Mean January Temper-ature	Housing Supply Elasticity	Share With College Degree, 2005-07*	Share With College Degree, 2014-18*	STEM Share of Employ-ment, 2019
Akron, OH	0.013	$55,001	26.8	2.59	27.8%	31.3%	3.79%
Albany-Schenectady-Troy, NY	0.065	58,502	23.3	1.70	31.6	36.8	5.96
Albuquerque, NM	0.224	45,084	36.7	2.11	29.1	31.6	6.70
Allentown-Bethlehem-Easton, PA-NJ	0.128	53,645	28.5	1.86	25.1	28.6	3.90
Ann Arbor, MI	0.134	58,125	24.5	2.29	51.3	55.2	8.07
Atlanta-Sandy Springs-Alpharetta, GA	0.326	54,664	44.0	2.55	33.5	37.8	6.03
Austin-Round Rock-Georgetown, TX	0.539	59,519	51.4	3.00	38.2	43.9	8.61
Bakersfield, CA	0.301	41,280	46.5	1.64	14.4	16.1	4.35
Baltimore-Columbia-Towson, MD	0.091	58,119	33.3	1.23	33.0	39.5	6.34
Baton Rouge, LA	0.155	52,518	50.9	1.74	24.3	27.7	4.17
Birmingham-Hoover, AL	0.102	58,312	44.1	2.14	25.6	29.6	4.45
Boston-Cambridge-Newton, MA-NH	0.102	69,109	29.9	0.86	40.8	47.2	7.59
Buffalo-Cheektowaga, NY	-0.034	53,018	25.0	1.83	26.1	31.8	3.76
Charleston-North Charleston, SC	0.357	52,895	48.4	1.20	28.6	34.8	3.74
Charlotte-Concord-Gastonia, NC-SC	0.391	55,515	40.8	3.09	31.2	34.7	4.75
Chicago-Naperville-Elgin, IL-IN-WI	0.041	59,731	25.1	0.81	31.8	37.4	4.77
Cincinnati, OH-KY-IN	0.090	60,061	30.3	2.46	27.1	33.0	4.77
Cleveland-Elyria, OH	-0.043	59,678	28.5	1.02	26.3	30.7	4.39
Colorado Springs, CO	0.313	49,402	30.8	1.67	33.6	37.8	7.77
Columbia, SC	0.248	48,927	45.7	2.64	29.3	31.9	4.28
Dallas-Fort Worth-Arlington, TX	0.365	56,469	47.2	2.49	29.5	34.4	5.93
Dayton-Kettering, OH	0.001	54,135	29.3	3.71	24.4	29.1	6.02
Denver-Aurora-Lakewood, CO	0.301	61,668	30.8	1.53	36.0	42.9	7.32
Detroit-Warren-Dearborn, MI	-0.029	55,049	25.3	1.24	26.1	30.6	7.11
El Paso, TX	0.210	40,947	46.0	2.35	18.0	22.7	2.76
Fort Wayne, IN	0.119	52,340	29.5	5.36	23.4	26.9	4.13
Fresno, CA	0.216	45,013	46.5	1.84	18.8	20.7	2.23
Grand Rapids-Kentwood, MI	0.133	53,204	24.5	2.39	25.7	32.4	3.75
Greensboro-High Point, NC	0.174	48,371	38.7	3.10	24.9	28.9	3.29
Greenville-Anderson, SC	0.220	48,970	41.8	2.71	25.6	28.6	3.69
Harrisburg-Carlisle, PA	0.120	54,047	31.7	1.63	27.3	31.7	5.00
Hartford-East Hartford-Middletown, CT	0.047	62,141	26.2	1.50	33.1	38.7	6.02
Houston-The Woodlands-Sugar Land, TX	0.394	56,143	54.2	2.30	27.3	32.4	5.93

(continued)

TABLE 2 (continued)
DATA FOR 83 METROPOLITAN AREAS

	Log Change, Popula-tion, 2000-18	Real Per Capita Personal Income, 2018	Mean January Temper-ature	Housing Supply Elasticity	Share With College Degree, 2005-07*	Share With College Degree, 2014-18*	STEM Share of Employ-ment, 2019
Indianapolis-Carmel-Anderson, IN	0.208	$59,801	28.5	4.00	29.7%	33.9%	4.78%
Jacksonville, FL	0.309	52,692	53.4	1.06	25.6	30.5	3.83
Kansas City, MO-KS	0.165	57,572	28.8	3.19	31.2	36.4	5.10
Knoxville, TN	0.165	52,266	38.4	1.42	27.0	28.5	4.38
Las Vegas-Henderson-Paradise, NV	0.471	49,338	48.8	1.39	20.4	22.7	2.37
Little Rock-North Little Rock-Conway, AR	0.191	50,527	40.4	2.79	26.9	30.1	4.61
Los Angeles-Long Beach-Anaheim, CA	0.070	54,557	56.5	0.63	29.2	33.7	5.08
Louisville/Jefferson County, KY-IN	0.146	55,917	34.5	2.34	23.3	28.6	3.82
Memphis, TN-MS-AR	0.105	51,748	41.2	1.76	23.9	27.7	3.08
Miami-Fort Lauderdale-Pompano Beach, FL	0.210	53,823	67.9	0.60	27.8	31.5	3.31
Milwaukee-Waukesha, WI	0.048	60,162	22.7	1.03	29.7	35.1	4.83
Minneapolis-St. Paul-Bloomington, MN-WI	0.177	61,320	15.9	1.45	36.6	41.2	6.31
Mobile, AL	0.028	45,063	50.2	2.04	19.3	22.9	3.84
Nashville-Davidson--Murfreesboro--Franklin, TN	0.334	61,938	38.4	2.24	28.2	34.8	3.96
New Haven-Milford, CT	0.039	51,504	30.0	0.98	30.9	34.9	5.15
New Orleans-Metairie, LA	-0.053	56,284	53.1	0.81	24.8	29.8	3.58
New York-Newark-Jersey City, NY-NJ-PA	0.050	61,696	32.5	0.96	34.6	39.4	4.68
Oklahoma City, OK	0.240	52,488	37.7	3.29	26.9	30.1	4.96
Omaha-Council Bluffs, NE-IA	0.203	62,295	24.6	3.47	31.7	35.8	5.36
Orlando-Kissimmee-Sanford, FL	0.440	44,293	60.2	1.12	27.4	31.3	4.11
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	0.069	60,937	32.7	1.65	31.3	37.0	5.49
Phoenix-Mesa-Chandler, AZ	0.395	47,440	56.0	1.61	26.6	30.8	5.55
Pittsburgh, PA	-0.044	62,520	28.3	1.20	27.2	34.1	4.75
Portland-Vancouver-Hillsboro, OR-WA	0.248	55,783	41.4	1.07	31.9	38.9	6.63
Providence-Warwick, RI-MA	0.022	54,284	29.2	1.61	27.4	31.4	4.28
Raleigh-Cary, NC	0.527	58,185	40.6	2.11	40.3	45.9	7.31
Richmond, VA	0.206	59,442	37.1	2.60	30.2	36.3	4.86
Riverside-San Bernardino-Ontario, CA	0.344	37,740	56.5	0.94	18.6	21.1	2.58
Rochester, NY	0.004	52,318	23.6	1.40	30.2	34.1	5.60
St. Louis, MO-IL	0.046	60,744	31.7	2.36	28.0	33.7	4.85
Salt Lake City, UT	0.260	52,837	30.4	0.75	29.1	33.9	6.04
San Antonio-New Braunfels, TX	0.381	50,425	51.5	2.98	23.9	27.7	4.18
San Diego-Chula Vista-Carlsbad, CA	0.168	52,532	57.9	0.67	33.2	38.1	6.88

(continued)

TABLE 2 (continued)
DATA FOR 83 METROPOLITAN AREAS

	Log Change, Popula-tion, 2000-18	Real Per Capita Personal Income, 2018	Mean January Temper-ature	Housing Supply Elasticity	Share With College Degree, 2005-07*	Share With College Degree, 2014-18*	STEM Share of Employ-ment, 2019
San Francisco-Oakland-Berkeley, CA	0.134	$76,167	50.0	0.66	42.5%	48.7%	7.87%
San Jose-Sunnyvale-Santa Clara, CA	0.140	83,899	50.0	0.76	43.2	50.4	16.29
Scranton--Wilkes-Barre, PA	-0.008	49,992	26.3	1.62	20.5	24.7	3.01
Seattle-Tacoma-Bellevue, WA	0.255	66,267	42.9	0.88	35.8	42.0	8.56
Springfield, MA	0.032	53,769	26.2	1.52	28.5	31.8	3.43
Stockton, CA	0.282	44,386	46.7	2.07	16.8	18.4	2.24
Syracuse, NY	0.001	51,766	23.6	2.21	26.9	31.5	4.43
Tampa-St. Petersburg-Clearwater, FL	0.268	47,810	61.3	1.00	25.1	29.6	4.20
Toledo, OH	-0.024	54,054	26.9	2.21	23.0	27.0	2.97
Tucson, AZ	0.203	46,874	53.5	1.42	29.6	31.9	5.83
Tulsa, OK	0.143	61,244	37.8	3.35	24.6	27.2	4.43
Vallejo, CA	0.118	42,474	50.0	1.14	22.3	26.2	3.54
Virginia Beach-Norfolk-Newport News, VA-NC	0.087	51,912	41.3	0.82	26.6	31.5	5.31
Washington-Arlington-Alexandria, DC-VA-MD-WV	0.250	61,409	33.3	1.61	46.1	50.6	9.34
Wichita, KS	0.108	56,875	32.2	5.45	25.4	30.3	7.09
Winston-Salem, NC	0.162	50,115	38.7	3.10	25.8	26.4	2.95
Youngstown-Warren-Boardman, OH-PA	-0.111	49,077	26.8	2.63	17.9	21.7	2.33

* The “share with college degree” is the share of the population age 25 and older with at least a bachelor’s degree. These data come from the American Community Survey (ACS), which began in 2005. In order to reduce sampling error, ACS data for multiple years are combined. Since estimates over a three-year period are no longer available, the more recent educational attainment measure combines five years of data.

Note: The 83 metro areas had at least 250,000 residents in 2000 and an estimate of the price elasticity of housing supply from Saiz (2010).

Sources: U.S. Department of Commerce, Bureau of Economic Analysis (per capita personal income and regional price parity); U.S. Department of Commerce, Census Bureau (population); U.S. Department of Commerce, Census Bureau, American Community Survey (educational attainment); U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Environmental Information (temperature); Saiz (2010) (housing supply elasticity); and Hill et al. (2021) (STEM).

TABLE 3
REGRESSION ANALYSIS OF POPULATION GROWTH BETWEEN 2000 AND 2018 IN 83 METROPOLITAN AREAS

Dependent Variable: Log Change in Population

Independent Variable	**Regression 1**	**Regression 2**	**Regression 3**
Mean January Temperature	0.0068*** (0.0012)	0.0075*** (0.0012)	
Elasticity of Housing Supply		0.033** (0.013)	-0.140*** (0.023)
Mean January Temperature Times the Elasticity of Housing Supply			0.0048*** (0.00063)
Constant	-0.091* (0.046)	-0.181*** (0.058)	0.095*** (0.027)
Adjusted R-Squared	0.290	0.333	0.413

Notes:
The sample consists of 83 Metropolitan Statistical Areas with a population in 2000 of at least 250,000 people and for which an estimate of the price elasticity of housing supply is available from Saiz (2010).

The value on the first line of each independent variable is the coefficient. The value in the second line in parentheses is the standard error. The statistical significance of an independent variable is indicated as follows: *** p < .01, ** p < .05, * p < .1. For example, a “p” (probability) of less than 0.05 indicates that the variable is significant at the 95 percent level of confidence.

Sources: U.S. Department of Commerce, Census Bureau (population); U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Environmental Information (temperature); and Saiz (2010) (housing supply elasticity).

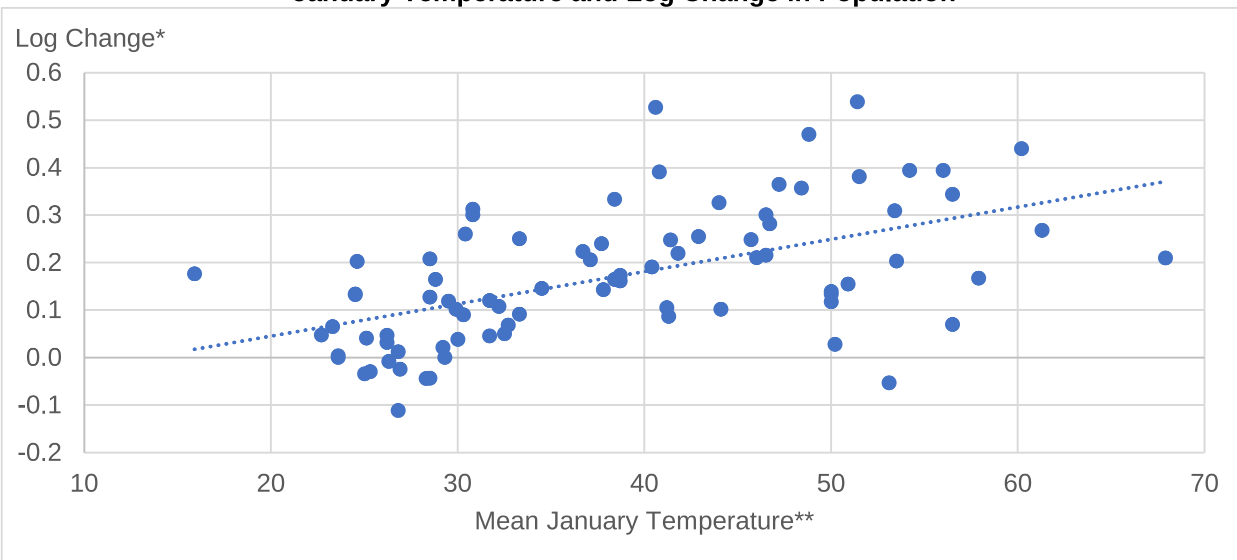
A comparison of scatter plots in Chart 4 provides visual evidence of the importance of housing supply in explaining urban population growth. In first scatter plot, January temperature is plotted against actual population growth. In the second scatter plot, population growth in a metro area is adjusted for the effect predicted from regression 3 of the deviation in the area's housing supply elasticity from the sample mean elasticity of 1.93. There is a tighter fit around the regression line in the second scatter plot.

It is useful to compare the regression errors in predicting population growth in regression 1 with those in regression 3 for selected large metro areas. The Atlanta, Dallas, and Houston metro areas each had population growth between 2000 and 2018 that was 12-to-14 percentage points greater than what would be expected on the basis of climate alone. Housing supply appears to account for most of that unexplained growth. When using regression 3 to adjust for their highly elastic housing supplies, the errors in predicting population growth fall to +5 percentage points in the cases of the Atlanta and Dallas metro areas, and to +2 percentage points in the case of Metro Houston.

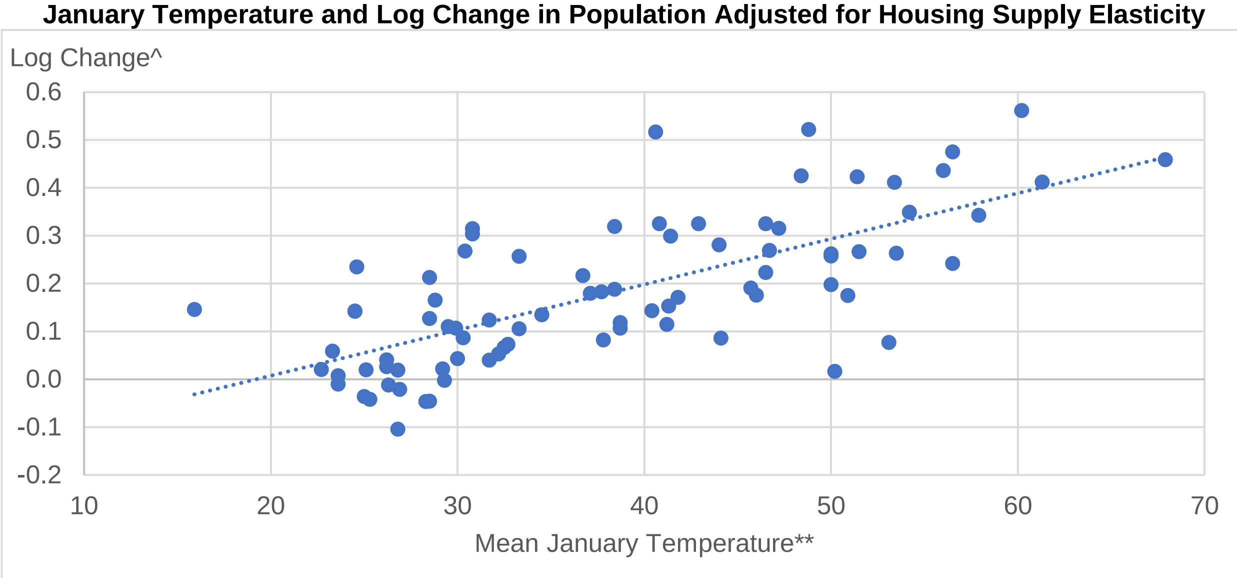
At the other extreme are areas with housing supplies that are estimated to be price inelastic — metro areas like Boston, Los Angeles, Miami, San Diego, San Francisco, and San Jose. In each of these areas, population growth between 2000 and 2018 was substantially slower than what would have been expected on the basis of climate alone — around 10 percentage points less growth for the Boston, San Francisco, and San Jose metro areas; 14-to-16 percentage points less for the Miami and San Diego metro areas; and 22 percentage points less in the case of Metro Los Angeles. After accounting for housing supply as well as climate, however, the errors in predicting population growth fall to 0 percentage points in the case of the Boston and Miami metro areas, -2 percentage points for Metro San Diego, and -3 percentage points for the San Francisco and San Jose metro areas. In Metro Los Angeles, the prediction error falls from -22 percentage points in regression 1 to -11 percentage points in regression 3.

CHART 4
POPULATION CHANGE BETWEEN 2000 AND 2018 AND JANUARY TEMPERATURE IN 83 METROPOLITAN AREAS

January Temperature and Log Change in Population



January Temperature and Log Change in Population Adjusted for Housing Supply Elasticity



* The change in population, as measured by natural logarithms, between 2000 and 2018.
** Mean (average of high and low) January temperature in Fahrenheit degrees from 1981 to 2010.
^ The change in population, as measured by natural logarithms, between 2000 and 2018 adjusted for housing supply elasticity from Saiz (2010).

Sources: U.S. Department of Commerce, Census Bureau (population); U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Environmental Information (temperature); and Saiz 2010 (housing supply elasticity).

HUMAN CAPITAL AS A PREDICTOR OF METROPOLITAN GROWTH

Educational Attainment

Numerous studies have found that the initial base of human capital in an urban area — as commonly measured by the percent of the population with a college degree — is a significant predictor of subsequent population growth in the area. Glaeser and Shapiro (2003) examined metro area data from the 1980, 1990, and 2000 censuses and found that the initial share of the metro population that is college educated is a significant predictor of subsequent decadal population growth. Glaeser and Saiz (2003) found that from 1980 to 2000, the population growth rate was higher in U.S. metro areas that had a high share of the adult population with a college degree. The authors found that this result holds after controlling for a variety of other variables and that it reflects causality that runs from human capital to growth. A positive association between initial years of schooling and subsequent population growth appears to have existed in every decade since 1900 (Simon and Nardinelli 2002).

A common explanation for the importance of local human capital as a determinant of urban growth centers on the concept of knowledge spillovers from Alfred Marshall's theory of industrial clusters. Through the sharing and rapid transmission of ideas, a concentration of educated workers in an urban area sets off a process of self-reinforcing growth and creates increasing returns. The interaction between education and technology affects the speed of its creation and adoption which is reinforced by flows of private investment and educated workers.[10]

Glaeser and Saiz (2003) tested for the relative validity of three alternative theories of why skills/education would affect urban growth: the "information city" view (Jacobs 1969), as described above, where cities help to facilitate the flow of ideas, and living around other skilled and educated people increases individual productivity; the "consumer city" view (Glaeser, Kolko and Saiz 2001) where educated people promote and support urban amenities which then attract more people; and the "reinvention city" view where education enables people to better adapt to economic change. When looking across metro areas, Glaeser and Saiz found that initial education levels are positively associated with nominal wage growth, housing price growth, and real wage growth. Based on these findings, the authors concluded that urban growth from 1980 to 2000 must have been driven more by increases in labor demand than increases in labor supply. Productivity-led growth, as in the information city view and the reinvention city view, would raise nominal wages and housing prices (which is observed) while consumption-led growth, as in the consumer city view, would lower real wages (which is not observed). Additional support for the reinvention city view comes from the finding that the relationship between skills and population growth is strongest in areas that have experienced a negative economic shock and that cities with high manufacturing intensity in 1940 switched out of manufacturing more rapidly if they had high education levels in 1940.

[10] An early expression of the thesis that cities serve as incubators for new ideas and innovation is Jacobs (1969). Empirical evidence for the existence of knowledge spillovers was first provided by Rauch (1993) who found that workers in a metro area with above-average educational attainment earned higher wages even after controlling for the productivity-enhancing attributes of the individual. Moretti (2004) later showed that Rauch's findings continue to hold after controlling for possible bias stemming from differences in the quality of individual human capital (the possibility that more productive workers with a given degree may locate in cities with more educated people).

An updated analysis of the significance of initial educational attainment for metro area growth is provided in Table 4. The sample consists of the same 83 metro areas analyzed in Table 3. The dependent variable is again the log change in population from 2000 to 2018. Added to the list of explanatory variables is the percent of the metro population aged 25 years and older that has a bachelor's degree or higher, as measured in the three-year American Community Survey from 2005 through 2007 (the data on college share are shown in Table 2).

In regression 4, the educational attainment variable is included as an explanatory variable additively, along with mean January temperature and housing supply elasticity. Initial educational attainment is positively associated with metro area population growth with a coefficient that is significant at the 99 percent level of confidence. When compared with regression 2 in Table 3, the adjusted R-squared increases from 0.33 to 0.41, and both the estimated coefficients and the t-values[11] of the other two explanatory variables increase in size.

In regression 5, the educational attainment variable is included interactively with the elasticity of housing supply, as was done in regression 3. The rationale for this specification is again the idea that the effects of both climate and initial educational attainment on population growth should go to zero as the elasticity of housing supply goes to zero. All variables are significant at the 99 percent level of confidence. The adjusted R-squared in regression 5 is the highest among all the regressions so far with a value of 0.54. When evaluated using the mean housing supply elasticity of 1.93, regression 5 indicates that a 10-percentage point increase in the initial college share increases metro population growth over the 2000-to-2018 period by 8.2 percentage points.

The positive association between initial college share and metro area population growth can be seen in the scatter plot shown in Chart 5. In this scatter plot, population growth in a metro area is adjusted for the effects predicted from regression 5 of the deviation in the area's January temperature from the sample mean January temperature of 38.2 degrees and for the deviation in the area's housing supply elasticity from the sample mean elasticity of 1.93.

Alternative Measures of Human Capital: STEM, the "Creative Class"

Because of the prominence of semiconductors, software, biotechnology, and other high-technology industries in high-performing national and local economies, including superstar metro areas such as Boston, San Francisco, and Seattle, there has been a particular emphasis in human capital policy on STEM education. Nathan Rothwell (2013) at the Brookings Institution used the O*NET[12] database from the U.S. Department of Labor to score occupations on the basis of their STEM knowledge requirements. He then used this information to analyze the importance of STEM skills to individual earnings and metro area economic performance. Using micro data for 2011, Rothwell confirmed the well-known result that individual earnings are higher in STEM occupations, after controlling for educational attainment and other individual productivity characteristics. Less obvious, but similar to results from earlier studies of knowledge and productivity spillovers from higher education, Rothwell found that the earnings of individuals in

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[11] The t-statistic is the ratio of the departure of the estimated value of a parameter from its hypothesized value to its standard error. It is used in hypothesis testing via Student's t-test. In the tables of regression results, the significance of an independent variable is determined from its t-value.
[12] The Occupational Information Network (O*NET) is a free online database that contains hundreds of occupational definitions (https://www.dol.gov/agencies/eta/onet).

TABLE 4
ADDITIONAL REGRESSION ANALYSIS OF POPULATION GROWTH BETWEEN 2000 AND 2018 IN 83 METROPOLITAN AREAS

Dependent Variable: Log Change in Population

Independent Variable	**Regression 4**	**Regression 5**	**Regression 6**	**Regression 7**	**Regression 8**
Mean January Temperature	0.0084***		0.0077***		0.0085***
	(0.0011)		(0.0011)		(0.0011)
Elasticity of Housing Supply	0.044***	-0.261***	0.037***	-0.190***	0.044***
	(0.013)	(0.033)	(0.013)	(0.028)	(0.013)
Mean January Temperature Times The Elasticity of Housing Supply		0.0052***		0.0049***	
		(0.00057)		(0.00060)	
Educational Attainment, 2005 Through 2007^	0.0066***				0.0082***
	(0.0020)				(0.0031)
Educational Attainment Times The Elasticity of Housing Supply		0.0042***			
		(0.00090)			
STEM Share of Employment in 2001			0.013**		-0.0062
			(0.0063)		(0.0096)
STEM Share of Employment Times The Elasticity of Housing Supply				0.0099***	
				(0.0034)	
Constant	-0.423***	0.073***	-0.264***	0.094***	-0.442***
	(0.090)	(0.025)	(0.068)	(0.026)	(0.095)
Adjusted R-Squared	0.410	0.536	0.361	0.464	0.406

(continued)

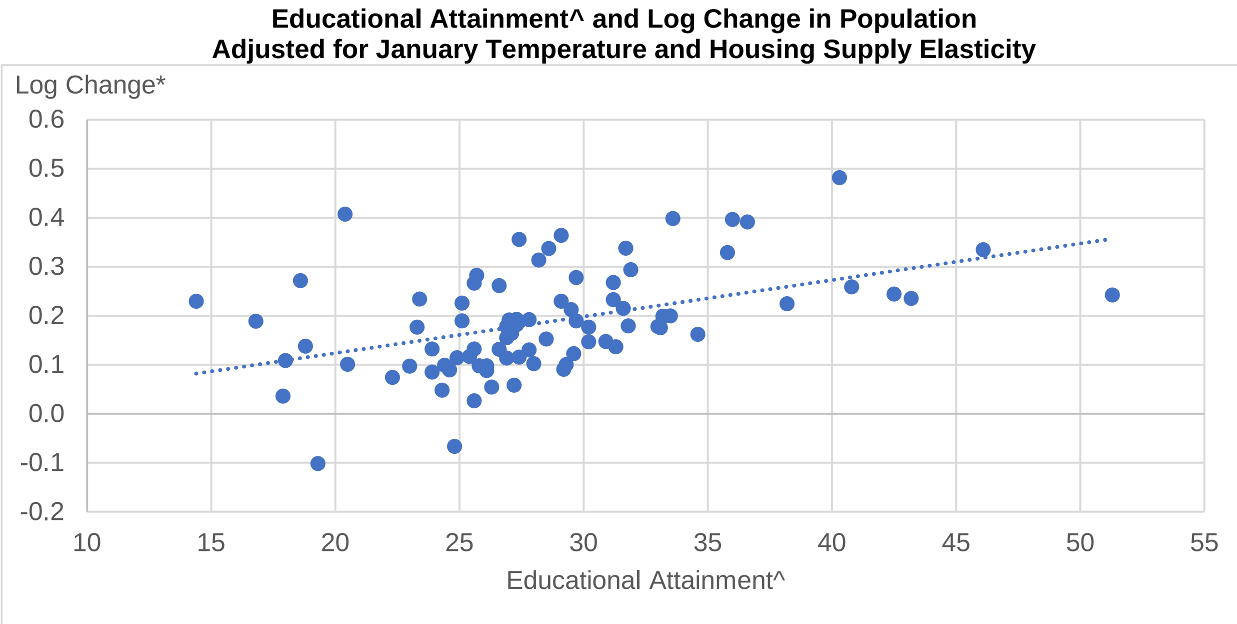
TABLE 4 (continued)
ADDITIONAL REGRESSION ANALYSIS OF POPULATION GROWTH BETWEEN 2000 AND 2018 IN 83 METROPOLITAN AREAS

^ Percent of the population aged 25 years and older with a bachelor's degree or higher.

Notes:
Sample consists of 83 Metropolitan Statistical Areas with a population in 2000 of at least 250,000 people and for which an estimate of the price elasticity of housing supply is available from Saiz (2010).

Standard errors in parentheses; *** $p < .01$, ** $p < .05$, * $p < .1$.
Sources: U.S. Department of Commerce, Census Bureau (population); U.S. Department of Commerce, Census Bureau, American Community Survey (educational attainment); U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Environmental Information (temperature); Saiz (2010) (housing supply elasticity); and Hill et al. (2021) (STEM).

CHART 5
POPULATION CHANGE BETWEEN 2000 AND 2018 AND EDUCATIONAL ATTAINMENT IN 83 METROPOLITAN AREAS



^ Percent of the population aged 25 years and older with at least a bachelor's degree in the period from 2005 through 2007.
* The change in population, as measured by natural logarithms, between 2000 to 2018 adjusted for mean January temperature and housing supply elasticity from Saiz (2010).

Sources: U.S. Department of Commerce, Census Bureau (population); U.S. Department of Commerce, Census Bureau, American Community Survey (educational attainment); U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Environmental Information (temperature); and Saiz (2010) (housing supply elasticity).

STEM occupations that require at least a four-year college degree are positively related to the overall STEM score of the resident metro area. Rothwell also showed that the most STEM-oriented metro areas had more patents per capita in 2011, more exports as a percent of gross product in 2010, and higher median household income in 2011.

Table 4 provides a regression analysis of the importance of the STEM share of metro area employment in 2001 as a predictor of population growth over the 2000-to-2018 period. The data on STEM share of employment are shown in Table 2.[13] Regressions 6 and 7 repeat the analyses of regressions 4 and 5, replacing the share of the adult population with at least a bachelor's degree with the share of employment in STEM occupations. The share of STEM employment is

[13] STEM employment was calculated from BLS data on employment by occupation. There were 81 occupations designated as STEM occupations: (1) three occupations from the "management" major group; (2) all of the occupations in the "computer and mathematical" major group; (3) the engineering portion of the "architecture and engineering" major group; and (4) the life and physical sciences portion of the "life, physical, and social science" major group. See Hill et al. (2021).

found to be a statistically significant predictor of future metro area population growth. Adding the STEM share of employment to a regression without any human capital variable improves the explanatory power of the regression. The adjusted R-squared increases from 0.33 to 0.36 in the additive regressions (2 versus 6) and from 0.41 to 0.46 in the interactive regressions (3 versus 7).

The initial STEM share of employment is not quite as good a predictor of future metro area population growth, however, as the initial college share in the population. Comparing regressions 4 and 6, for example, the adjusted R-squared falls from 0.41 to 0.36 when the college share is replaced with the STEM share. The coefficients and t-values of the January temperature and housing supply variables are also lower in the STEM regression. Regression 8 shows what happens when the STEM share is added to regression 4, which already has the college share as an explanatory variable. The coefficient on the STEM share has the wrong sign, although it is statistically insignificant, and the adjusted R-squared falls slightly. The simple correlation coefficient[14] between the STEM share and the college share is 0.77, which explains why a regression with the STEM share as the only human capital variable would perform better than a regression without any human capital variable.

In best-selling books on regional economics that quickly became a must read among urban policy makers, Richard Florida (2002, 2012) proposed an alternative way of identifying and measuring the human capital in an urban area that was integral to innovation and the production of new ideas. Rather than using educational attainment, he recommended using employment in occupations that were prominent in knowledge-intensive industries and in which work centered on creative problem solving or the production of new ideas. In Florida's way of thinking, it was creativity and talent that were crucial, not whether an individual held a high-level academic degree. Florida's "creative class" consisted not only of engineers, biochemists, mathematical programmers and workers in other STEM occupations, but doctors, lawyers, management consultants and financiers. Especially important, in his view, were people in "super creative" occupations: university professors, designers, entertainers, musicians, novelists, and poets.

Florida's thesis was that urban growth and success in the new economy required a concentration or cluster of individuals in creative occupations. Because people are mobile, he recommended to urban planners that they focus on developing the kind of urban amenities that appeal to creative workers, especially to those seeking a bohemian lifestyle: entertainment venues, places to meet, natural beauty and open space, and, above all, a culture of tolerance and openness. In stressing the importance of consumption amenities as a way of attracting skilled workers to an urban area, Florida was not far apart in his ideas from those expressed in an earlier paper by Glaeser, Kolko, and Saez (2001).

Florida (2014) cited several studies that concluded that creative-class occupational measures of human capital were more successful in predicting urban growth and development than education-based measures. But other authors have reached different conclusions. In a review of Florida's book, Glaeser (2005) conducted a simple empirical experiment. He started with educational attainment (expressed as the percent of the population with a bachelor's degree) as the sole independent variable in a regression explaining U.S. metro area population growth during the

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[14] Correlation coefficients are used to measure the strength of the relationship between two variables. Values range from 1 (perfect positive correlation) to -1 (perfect inverse correlation).

1990s and then sequentially added some of the creative-class variables suggested by Florida to see if they improved the explanatory power of the regression. When adding a variable measuring the share of metro area employment in “super creative” occupations, the creative-class variable had the wrong sign and was statistically insignificant, while the education variable had a positive and statistically significant coefficient. A variable measuring tolerance in the local community (the “Gay Index”) also ended up insignificant and with the wrong sign. When a variable measuring the prominence of artistic types in the local population (the “Bohemian Index”) was added to the regression, the education variable became statistically insignificant and the creative-class variable was positive and significant. However, Glaeser traced this result to two observations: Las Vegas, Nevada and Sarasota, Florida. When these two observations were dropped and the remaining 240 observations were reanalyzed, the creative-class variable became insignificant and the education variable once again took over. Glaeser concludes that while occupational data offer a promising alternative to educational data in measuring the human capital base of an area, the particular creative-class variables suggested by Florida do not do as a good a job of predicting urban population growth as more traditional education-based variables.

DETERMINANTS OF HOUSE PRICE INFLATION

According to the Rosen-Roback spatial equilibrium model, urban success should reveal itself in the form of both population growth and house price inflation. The less elastic is the supply of housing, the smaller the effect on population growth and the larger the effect on house price inflation. Table 5 shows the results of regressions of house price inflation over the 2000-to-2018 period on the same explanatory variables used in analyzing metro area population growth. Data on house price inflation are from the Federal Housing Finance Agency. The sample consists of 74 metro areas — the 83 metro areas used in the analysis of urban population growth less nine metro areas for which house price inflation data are unavailable.

Focusing on regression 3 in Table 5, each of the coefficients has the expected sign and each is statistically significant at the 99 percent level of confidence. January temperature and initial educational attainment are positively related to house price inflation, as they are to population growth. As expected from theory, the elasticity of housing supply is positively related to population growth but negatively related to house price inflation. With an adjusted R-squared of 0.50, the three explanatory variables in regression 3 combine to explain a substantial amount of the variation in house price inflation across the 74 metro areas.

TABLE 5
REGRESSION ANALYSIS OF HOUSE PRICE INFLATION BETWEEN 2000 AND 2018 IN 74 METROPOLITAN AREAS

	Dependent Variable: Log Change in House Price Index		
	Regression 1	**Regression 2**	**Regression 3**
Independent Variable			
Mean January Temperature	0.0099***	0.0085***	0.0099***
	(0.0017)	(0.0016)	(0.0016)
Elasticity of Housing Supply		-0.077***	-0.060***
		(0.020)	(0.019)
Educational Attainment, 2005 Through 2007^			0.0111***
			(0.0031)
Constant	0.230***	0.430***	0.028
	(0.071)	(0.082)	(0.136)
Adjusted R-Squared	0.299	0.416	0.497

^ Percent of the population aged 25 years and older with a bachelor's degree or higher.

Notes:
Sample consists of 74 Metropolitan Statistical Areas with a population in 2000 of at least 250,000 people, for which an estimate of the price elasticity of housing supply is available from Saiz (2010) and for which data on house price inflation are available.

Standard errors in parentheses; *** p < .01, ** p < .05, * p < .1.

Sources: U.S. Department of Commerce, Census Bureau, American Community Survey (educational attainment); U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Environmental Information (temperature); Federal Housing Finance Agency (house price index); and Saiz (2010) (housing supply elasticity).

EXPLAINING DIFFERENCES IN EARNINGS AND INCOMES ACROSS METROPOLITAN AREAS

Real Earnings Per Worker

If workers/households are mobile and move to arbitrage differences in utilities[15] across locations, then in a spatial equilibrium differences in average real earnings between areas should reflect differences in human capital and compensate for differentials in urban amenities, with real earnings being lower in areas with greater amenities. Tables 6 and 7 show the results of a regression analysis of determinants of real earnings per worker in 2018. Variations in earnings per worker across metro areas are explained by differences in levels of human capital and differences in mean January temperature (as a potentially significant amenity variable). Human capital levels are measured in three ways: as the share of the population 25 years and older with a bachelor's degree or higher, the percent of the labor force between the ages of 25 and 64 with at least a bachelor's degree, and the percent of those employed who work in STEM occupations.

Two measures of earnings per worker are examined: (1) employee compensation per worker, defined as the sum of wages, salaries, and benefits divided by the number of wage and salary workers; and (2) labor income per worker, defined as the sum of employee compensation and proprietors' income divided by total employment (the number of wage and salary workers plus the number of proprietors). Each measure is adjusted for differences in the cost of living across metro areas using the regional price parities produced by the U.S. Department of Commerce, Bureau of Economic Analysis.

Two basic samples of metro areas are analyzed — the 171 metros with a population of at least 250,000 in 2000 and the smaller sample of 83 metros (as in Tables 3 and 4). The metro areas in the smaller sample tend to have larger populations than the ones in the larger sample. In the small sample, only 5 percent of metro areas had a population in 2018 that was less than 500,000. In the larger sample, 37 percent of metro areas had a population less than 500,000. Because Metro San Jose is an outlier in having an unusually high percentage of its workforce in STEM occupations and unusually high earnings per worker, it is also useful to examine results for samples in which the San Jose metro area is omitted.[16]

According to the results in Tables 6 and 7, of the three explanatory variables considered, the STEM share of employment is far and away the most important determinant of earnings per worker. The STEM variable is significant at a 99 percent level of confidence in each of the 16 regressions. In regressions with employee compensation per worker as the dependent variable, for example, the estimated coefficients on the STEM variable range from a low of 1,396 to a high of 2,878. For some perspective, the STEM share of employment in Metro Austin was 9.0 percent in 2019 while in Metro Phoenix, the STEM share of employment was 5.8 percent. The

[15] Economic utility relates to the satisfaction received after utilization of an item. In this case, it refers to the satisfaction/well-being an individual receives from living in one location versus another. Arbitrage refers to taking advantage of differences between locations to maximize utility.

[16] The average value for the STEM share of employment in the sample of 83 metro areas is 5.6 percent. Metro San Jose's STEM share is 18.4 percent. The metro with the next highest STEM share is Seattle with a share of 10.3 percent. Metro San Jose also has unusually high compensation per worker — a value of $116,500 as compared with a sample mean of $70,400 and a value of $87,100 in San Francisco, the metro with the next highest compensation per worker.

TABLE 6
REGRESSION ANALYSIS OF REAL EARNINGS PER WORKER IN 2018 IN 171 METROPOLITAN AREAS

	Dependent Variable: Real Compensation Per Worker^				Dependent Variable: Real Labor Income Per Worker^^			
Independent Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Educational Attainment, 2014 to 2018#	-131.7		-60.1		-182.8**		-105.5	
	(81.1)		(79.9)		(87.1)		(85.7)	
Workforce Educational Attainment, 2014 to 2018##		-25.0		54.4		-73.4		11.8
		(81.2)		(79.5)		(87.5)		(85.7)
STEM Share of Total Employment, 2019	2,655.4***	2,394.2***	2,144.9***	1,826.2***	2,283.5***	2,021.8***	1,732.5***	1,411.7***
	(263.6)	(272.7)	(284.2)	(291.9)	(283.1)	(293.8)	(305.1)	(314.6)
Mean January Temperature	-81.1**	-77.6**	-100.3***	-93.8***	-158.8***	-158.0***	-179.6***	-175.4***
	(32.7)	(33.8)	(31.7)	(32.4)	(35.1)	(36.4)	(34.1)	(34.9)
Constant	61,336***	59,319***	62,314***	59,879***	60,252***	58,463***	61,307***	59,065***
	(2,382.2)	(2,741.9)	(2,298.6)	(2,614.5)	(2,558.1)	(2,954.3)	(2,467.2)	(2,818.0)
Number of Observations	171	171	170	170	171	171	170	170
Adjusted R-Squared	0.558	0.551	0.475	0.475	0.459	0.447	0.388	0.383

^ Employee compensation (wages, salaries, and benefits) divided by the number of wage and salary workers adjusted for the cost of living.
^^ Employee compensation plus proprietors' income divided by total employment (wage and salary employment plus the number of proprietors) adjusted for the cost of living.

Percent of the population aged 25 years and older with a bachelor's degree or higher.
Percent of the population in the labor force aged 25 to 64 with a bachelor's degree or higher.

Notes:
Sample consists of 171 metropolitan areas with a population in 2000 of at least 250,000 people. In regressions with 170 observations, the San Jose metro area has been omitted.

Standard errors in parentheses; *** p < .01, ** p < .05, * p < .1.

Sources: U.S. Department of Commerce, Bureau of Economic Analysis (compensation per worker, labor income per worker, and regional price parity); U.S. Department of Commerce, Census Bureau, American Community Survey (educational attainment); U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Environmental Information (temperature); and Hill et al. (2021) (STEM).

TABLE 7
REGRESSION ANALYSIS OF REAL EARNINGS PER WORKER IN 2018 IN 83 METROPOLITAN AREAS

	Dependent Variable: Real Compensation Per Worker^				Dependent Variable: Real Labor Income Per Worker^^			
Independent Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Educational Attainment, 2014 to 2018#	-55.2		166.4		-205.8		13.1	
	(117.4)		(121.0)		(136.0)		(144.1)	
Workforce Educational Attainment, 2014 to 2018##		70.6		258.5**		-80.8		112.1
		(106.5)		(103.8)		(125.5)		(127.2)
STEM Share of Total Employment, 2019	2,877.5***	2,565.1***	1,678.8***	1,396.2***	2,768.1***	2,461.2***	1,584.0***	1,278.0***
	(353.1)	(333.0)	(441.0)	(392.8)	(409.0)	(391.9)	(524.9)	(481.2)
Mean January Temperature	-27.7	-11.8	-41.7	-19.2	-141.8***	-135.1**	-155.7***	-143.7***
	(42.6)	(44.4)	(39.2)	(39.7)	(49.4)	(51.7)	(46.7)	(48.0)
Constant	57,053***	53,733***	56,769***	53,232***	59,471***	57,220***	59,191***	56,631***
	(3,341.2)	(3,753.9)	(3,063.6)	(3,358.1)	(3,870.1)	(4,390.8)	(3,646.5)	(4,071.1)
Number of Observations	83	83	82	82	83	83	82	82
Adjusted R-Squared	0.693	0.694	0.541	0.564	0.559	0.548	0.386	0.392

^ Employee compensation (wages, salaries, and benefits) divided by the number of wage and salary workers adjusted for the cost of living.
^^ Employee compensation plus proprietors' income divided by total employment (wage and salary employment plus the number of proprietors) adjusted for the cost of living.

Percent of the population aged 25 years and older with a bachelor's degree or higher.
Percent of the population in the labor force aged 25 to 64 with a bachelor's degree or higher.

Notes:
Sample consists of 83 metropolitan areas with a population in 2000 of at least 250,000 people for which an estimate of the price elasticity of housing supply is available from Saiz (2010). In regressions with 82 observations, the San Jose metro area has been omitted.

Standard errors in parentheses; *** p < .01, ** p < .05, * p < .1.

Sources: U.S. Department of Commerce, Bureau of Economic Analysis (compensation per worker, labor income per worker, and regional price parity); U.S. Department of Commerce, Census Bureau, American Community Survey (educational attainment); U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Environmental Information (temperature); and Hill et al. (2021) (STEM).

coefficients estimated for STEM share indicate that this difference in STEM intensity of employment makes average annual compensation per worker in Metro Austin $4,500 to $9,200 higher than it is in Metro Phoenix.

The sample characteristic with the most significant impact on the estimated STEM coefficient is whether or not the San Jose metro area is included in the analysis. The estimated STEM coefficient is significantly larger in samples that include Metro San Jose, especially in the smaller sample of 83 metro areas. The estimated STEM coefficient also varies in a consistent way with the definition of educational attainment. When educational attainment is measured as a percent of the labor force of ages 25 to 64 rather than percent of the 25 and older population, the STEM coefficient decreases in size, and the coefficient on educational attainment increases.

The regression analysis does not show educational attainment — measured by the share with a bachelor's degree either in the population or in the workforce — to be a significant determinant of earnings per worker. The estimated coefficients for educational attainment are small in size, often have the wrong sign, and are statistically significant in only one of the 16 regressions. This result is surprising in view of the well-known tendency for workers with college degrees to earn more than workers without college degrees. It is the case that college earnings premiums are especially large for those with degrees in STEM fields (Hill 2018), and STEM is to some extent controlled for in the regressions. However, workers with degrees in business fields such as economics, finance, and accounting also have earnings that are well above the average earnings of those without college degrees. In fact, workers with a bachelor's degree in almost any field (with the possible exception of education) earn more on average than those without a college degree. The education and STEM variables are highly correlated.[17] But it is not clear why the STEM variable would pick up some of the effects of higher education and not vice versa. It may be that non-STEM occupations requiring a college degree are more evenly distributed across metro areas than are STEM occupations.

Mean January temperature is also included in the regressions as a possible determinant of earnings per worker. Warm winters have proven to be a powerful attractor for people and jobs in U.S. metro areas over the past 50 years. To the extent that this partly reflects a preference among households for living in warm climates, one would expect January temperature to be negatively related to real per capita earnings. The coefficient on January temperature is indeed negative and statistically significant in each of regressions for the large sample of metro areas. The coefficient also is negative and significant in the small sample when earnings are broadly defined to include proprietors' income. In regressions where the dependent variable is labor income per worker, the climate coefficient ranges in size from 135 to 180. This means that an increase in mean January temperature of 31 degrees, equivalent to what would be experienced in moving from Chicago to Phoenix, is worth between $4,200 and $5,600 per person.

It is notable that the coefficient for January temperature is more negative in regressions where the dependent variable is labor income per worker than in regressions with employee compensation per worker as the dependent variable. One explanation for this result could be that those who are self-employed are more mobile and have more freedom to select their place of

[17] The correlation coefficient between the bachelor's degree or more share in the workforce and the STEM share of employment is around 0.78 in both samples.

residence than do wage and salary workers. Another explanation is that it is easier to start a business in areas of the country with warm climates (i.e., the South and Southwest).

Real Per Capita Income

A variable frequently used to measure prosperity and economic performance in an urban area is per capita personal income. Per capita income will vary with earnings per worker, the percent of the population that is employed, and the importance of nonearnings income, such as property income and Social Security benefits, to the average resident. Tables 8 and 9 show the results of a regression analysis of determinants of real per capita income in 2018. Explanatory variables used in the analysis are some of the variables used to explain earnings per worker (human capital variables and climate), two measures of the employment-to-population ratio, and, as an indicator of the importance of nonearnings income, the percent of the metro population that is 65 years and older. The samples of metro areas analyzed are the same as those used in the earnings analysis.

The most striking conclusion from the regressions is that when analyzing per capita income rather than earnings per worker, the dominant human capital variable is the share in the population with at least a bachelor's degree, not the STEM share of employment. The estimated coefficients for the college share variable are large in size and significant at the 99 percent level of confidence in 11 of the 12 regressions. The STEM variable, on the other hand, is significant only in the small sample that includes Metro San Jose. As will be explained further below, much of the significance of the college share variable derives from the fact that it is positively related to the percent of the population that is employed, either as wage and salary workers or as proprietors.

The coefficients on the climate variable are once again negative but smaller in size and less significant than they were in the earnings per worker regressions. This is not surprising given that personal income includes capital income, which is portable. One does not have to accept lower capital income to live in an area with a warm climate (or lower real capital income if the area has an elastic housing supply). Indeed, the tendency for retired people to choose to live in areas with warm winters serves to foster a positive relationship between mean January temperature and per capita personal income. The estimated climate coefficients are less negative in the large sample regressions than in the small sample regressions because the large sample includes many Florida retirement communities that are not in the 83-metro-area sample.

As expected, the coefficients on the variable measuring the elderly share in the population are positive and statistically significant, especially in the large sample regressions. The larger size of the coefficients in the large sample is due once again to a greater representation of retirement communities in that sample. The 171-metro-area sample includes 13 metros with an elderly share of the population that is 20 percent or higher. Only one of those metros is in the 83-metro-area sample.

Earnings per capita, the major component of per capita personal income, will depend not only on earnings per worker but also on the percent of the population that is employed. Two measures of the employment-to-population ratio were considered: the ratio of wage and salary workers to the population and the ratio of total employment (including the number of proprietors) to the

TABLE 8
REGRESSION ANALYSIS OF REAL PER CAPITA PERSONAL INCOME IN 2018 IN 171 METROPOLITAN AREAS

Dependent Variable: Real Per Capita Personal Income

Independent Variable	**Regression 1**	**Regression 2**	**Regression 3**	**Regression 4**	**Regression 5**	**Regression 6**
Educational Attainment, 2014 to 2018^	711.9***	721.5***	703.1***	684.5***	536.1***	333.5***
	(65.6)	(103.9)	(104.2)	(100.8)	(108.0)	(120.4)
STEM Share of Total Employment, 2019		-40.5	-65.4	200.4	89.2	245.8
		(339.7)	(338.7)	(335.8)	(328.1)	(316.2)
Mean January Temperature			-64.5	-77.6*	-15.6	-34.6
			(42.0)	(40.7)	(43.9)	(39.4)
Share of Population 65 and Older, 2014 to 2018				522.9***	623.0***	661.7***
				(146.7)	(145.8)	(141.2)
Wage and Salary Employment-to-Population Ratio, 2018					380.3***	
					(116.1)	
Total Employment-to-Population Ratio, 2018						495.1***
						(104.6)
Constant	31,041***	30,949***	34,163***	25,816***	8,899	2,606.3
	(2,098.7)	(2,243.7)	(3,060.4)	(3,773.2)	(6,333.7)	(6,052.3)
Number of Observations	171	171	171	171	171	171
Adjusted R-Squared	0.407	0.404	0.408	0.447	0.478	0.510

^ Percent of the population aged 25 years and older with a bachelor's degree or higher.

Notes:
Sample consists of 171 metropolitan areas with a population in 2000 of at least 250,000 people.

Standard errors in parentheses; *** p < .01, ** p < .05, * p < .1.

Sources: U.S. Department of Commerce, Bureau of Economic Analysis (per capita personal income, employment, population, and regional price parity); U.S. Department of Commerce, Census Bureau, American Community Survey (educational attainment); and U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Environmental Information (temperature); and Hill et al. (2021) (STEM).

TABLE 9
REGRESSION ANALYSIS OF REAL PER CAPITA PERSONAL INCOME IN 2018 IN 83 METROPOLITAN AREAS

Dependent Variable: Real Per Capita Personal Income

Independent Variable	**Regression 1**	**Regression 2**	**Regression 3**	**Regression 4**	**Regression 5**	**Regression 6**
Educational Attainment, 2014 to 2018^	482.3***	647.0***	414.7***	578.9***	393.0***	238.5*
	(124.0)	(137.2)	(123.5)	(133.1)	(135.7)	(139.6)
STEM Share of Total Employment, 2019	1,021.5***	153.7	1,227.0***	312.6	324.8	510.5
	(379.4)	(507.1)	(372.1)	(490.6)	(459.0)	(438.5)
Mean January Temperature			-99.7**	-114.3**	-39.1	-82.8**
			(46.6)	(45.1)	(47.5)	(40.7)
Share of Population 65 and Older, 2014 to 2018			301.0	227.8	288.9	349.7*
			(239.8)	(232.1)	(217.9)	(208.1)
Wage and Salary Employment-to-Population Ratio, 2018					426.6***	
					(123.4)	
Total Employment-to-Population Ratio, 2018						459.2***
						(99.5)
Constant	33,099***	32,367***	33,594***	34,754***	15,970**	13,046*
	(2686.7)	(2620.4)	(5705.9)	(5501.2)	(7485.0)	(6789.0)
Number of Observations	83	82	83	82	82	82
Adjusted R-Squared	0.588	0.521	0.618	0.563	0.617	0.654

^ Percent of the population aged 25 years and older with a bachelor's degree or higher.

Notes:
Sample consists of 83 metropolitan areas with a population in 2000 of at least 250,000 people for which an estimate of the price elasticity of housing supply is available from Saiz (2010). In regressions with 82 observations, the San Jose metro area has been omitted.

Standard errors in parentheses; *** p < .01, ** p < .05, * p < .1.

Sources: U.S. Department of Commerce, Bureau of Economic Analysis (per capita personal income, employment, population, and regional price parity); U.S. Department of Commerce, Census Bureau, American Community Survey (educational attainment); U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Environmental Information (temperature); and Hill et al. (2021) (STEM).

population. Each measure is statistically significant at the 99 percent level of confidence in each table. The estimated coefficients are large in size. Using the coefficient from regression 6 in Table 9, for example, the results indicate that because Metro Phoenix has a lower total employment-to-population ratio than does Metro Denver (57.5 percent versus 71.2 percent), per capita personal income in the Phoenix area will tend to be $6,300 lower than it is in the Denver area.

Notable from the regressions that include one of the employment-to-population ratios is that the inclusion of these variables substantially reduces the estimated coefficients of the educational attainment variable. Much of the effect that educational attainment was found to have had on per capita personal income in other regressions derives from the fact that metro areas with a highly educated population also have high employment-to-population ratios. The higher is the college share in the population, the larger is the percent of the population employed as wage and salary workers and the larger the percent that is self-employed.[18]

[18] In regressions of alternative employment-to-population ratios on college share and the other explanatory variables in the model, college share is significant in all cases at a 99 percent level of confidence. Depending on the sample, the estimated coefficients indicate that a 10-percentage point increase in college share increases the total employment-to-population ratio by 7.1-to-7.4 percentage points, with 55-to-60 percent of that increase taking the form of a higher ratio of wage and salary employment to population and the remaining 40-to-45 percent arising from an increase in the percent of the population that is self-employed.

RECENT DIVERGENCE IN LEVELS OF HUMAN CAPITAL ACROSS METROPOLITAN AREAS

From 1880 to 1980, disparities in per capita incomes and productivities across regions of the United States and other advanced countries systematically narrowed. In American states, income gaps closed at an average annual rate of 1.8 percent. A similar convergence of incomes occurred in regions of major European nations and in Japan. Then beginning in the 1980s, regional convergence slowed. In American states, the rate of convergence of incomes slowed to less than half of what it had been during the previous 100 years. At the same time, the most productive and prosperous areas began to pull away from other areas. From 2005 to 2015, productivity growth in U.S. metro areas was most rapid in the top 10 percent. Regional economic divergence has also been occurring in other advanced countries. Since the mid-1990s, the average productivity gap in The Organisation for Economic Co-operation and Development (OECD) countries has widened by 60 percent between the most productive 10 percent of regions and the bottom 75 percent (*The Economist* 2017).

Contributing to the end of regional income convergence in the United States has been a divergence across areas in levels of human capital. The fact that metro areas like Boston and San Francisco, that were already well educated in the 1980s, were experiencing large increases in the shares of their workforce that were highly educated was a part of what Enrico Moretti referred to in his book *The New Geography of Jobs* (2012) as “The Great Divergence.” Berry and Glaeser (2005) were among the first to systematically identify for a large sample of metro areas a positive correlation between the initial share of the adult population that had a college degree and the size of the increase in that college share over the subsequent decade. Moretti (2013) similarly found a positive correlation between these variables for the 1980-to-2000 period while showing that, since college graduates were disproportionately locating in areas with a high cost of housing, evidence of a growing nominal college wage premium overstated the rise in the real college wage premium.

Explanations which have been given for the recent divergence in human capital levels across metro areas are varied. But based on observations of rising wages in areas with large increases in human capital, there is broad agreement that the underlying factors primarily involve an increase in the demand for skilled labor rather an increase in the supply of skilled labor to areas with amenities that appeal to skilled workers.

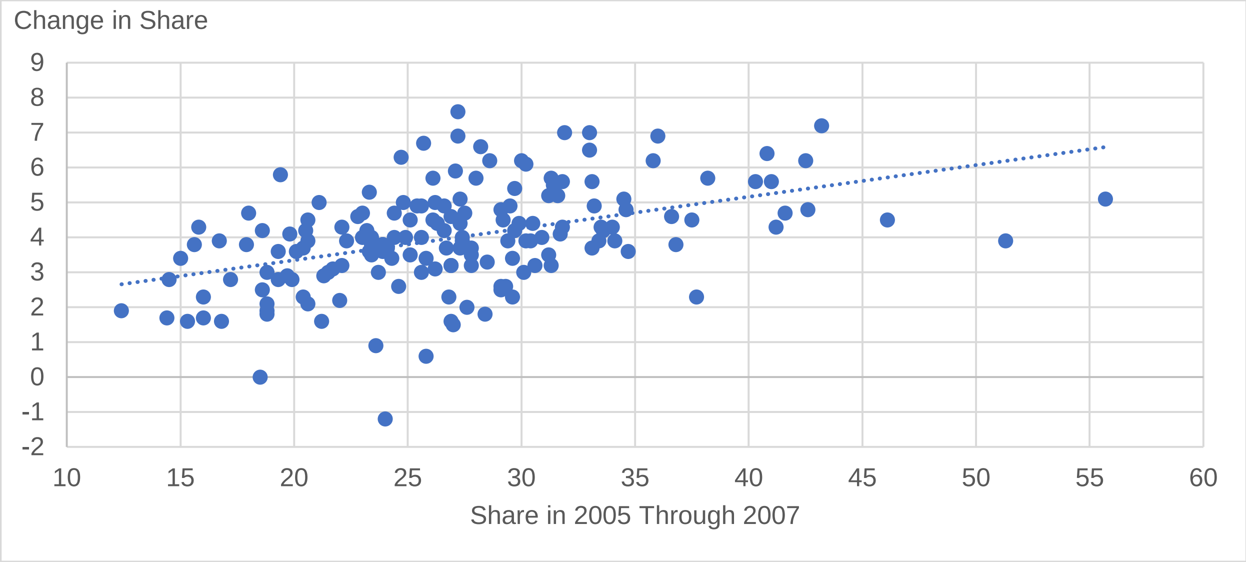
Berry and Glaeser (2005) used a highly specific model of urban agglomeration to explain the phenomenon of increasing urban concentration of skilled workers as the result of a growing tendency for innovation to be carried out by high-skilled entrepreneurs who start firms that hire other skilled people. Moretti (2012) similarly emphasized the increasing importance of clustering and agglomeration economies in innovation industries — those that intensively employ highly educated workers. The staff at *The Economist* (2017) argued that forces of globalization and international competition have encouraged export-base industries, which intensively use highly skilled labor, to seek and realize greater efficiencies from clustering. An additional element in the narrative of many authors (Berry and Glaeser 2005; Gyourko, et al. 2013; and Diamond 2016) is that in areas with restrictive housing policies and inelastic housing supplies, an increase in the demand for skilled labor drives up housing costs that, in turn, causes an outmigration of low-skilled labor in search of less-expensive places to live.

An empirical update to earlier findings of divergence in human capital levels is provided for both education-based and STEM-based measures of human capital. Chart 6 shows for the sample of 171 metro areas that there is a significant positive correlation between the share of the adult population in 2005 through 2007 with at least a bachelor's degree and the change in share from the 2005-to-2007 period to the 2014-to-2018 period. The coefficient on initial college share (expressed as a percent) in a univariate regression is 0.091 with a standard error of 0.014. The adjusted R-squared in the regression is 0.20.

Table 10 provides a list of selected metro areas in which the share of the adult population with at least a bachelor's degree has increased the most and the least. The first data column in the table shows the actual change in college share, while the second data column reports whether the change in college share was greater or less than what would be expected from the regression line in Chart 6. Among metro areas with the largest gains in college share are the large information technology and innovation hubs of the San Jose, Boston, Seattle, and San Francisco metro areas. These metro areas had gains in college share that were not only large in absolute terms but gains that exceeded what would be expected on the basis of their initial college shares. Also among metros with large gains in college share are the Asheville, Denver, and Nashville metro areas — places with cultural and natural amenities that have made them increasingly desirable places to live.

CHART 6
DIVERGENCE IN LEVELS OF HUMAN CAPITAL
AS MEASURED BY EDUCATIONAL ATTAINMENT

Share of the Population 25 and Older With At Least a Bachelor's Degree in 2005 Through 2007 and the Change in Share From 2005 Through 2007 to 2014 Through 2018



Source: U.S. Department of Commerce, Census Bureau, American Community Survey.

TABLE 10
PERCENTAGE-POINT CHANGE IN EDUCATIONAL ATTAINMENT BETWEEN 2005 THROUGH 2007 AND 2014 THROUGH 2018 IN SELECTED METROPOLITAN AREAS

	Change in Share of the Population 25 and Older With At Least a Bachelor's Degree	Regression Residual
High Performers:		
Asheville, NC	7.6	3.6
San Jose-Sunnyvale-Santa Clara, CA	7.2	1.7
Portland-Vancouver-Hillsboro, OR-WA	7.0	2.6
Pittsburgh, PA	6.9	2.9
Denver-Aurora-Lakewood, CO	6.9	2.1
Nashville-Davidson--Murfreesboro--Franklin, TN	6.6	2.5
Baltimore-Columbia-Towson, MD	6.5	2.0
Boston-Cambridge-Newton, MA-NH	6.4	1.2
Seattle-Tacoma-Bellevue, WA	6.2	1.4
San Francisco-Oakland-Berkeley, CA	6.2	0.8
Low Performers:		
Knoxville, TN	1.5	-2.5
Bakersfield, CA	1.7	-1.1
Fresno, CA	1.9	-1.3
Tucson, AZ	2.3	-1.9
Las Vegas-Henderson-Paradise, NV	2.3	-1.1
Albuquerque, NM	2.5	-1.7
Riverside-San Bernardino-Ontario, CA	2.5	-0.7

Source: U.S. Department of Commerce, Census Bureau, American Community Survey (educational attainment) and univariate regression presented in Chart 6.

Among the metro areas with the smallest gains in college share are farming and immigrant areas in California. Metro Tucson also experienced a small gain in college share. Metro Phoenix, on the other hand, registered an increase in the bachelor's degree or more share of 4.2 percentage points, which was about what would be expected given its initial share.

Chart 7 shows for a smaller sample of larger metro areas (where STEM activities seem to matter more for real per capita income) a positive correlation between the STEM share of employment in 2001 and the change in STEM share from 2001 to 2019.[19] The coefficient on the initial STEM share in a univariate regression is 0.138 with a standard error of 0.038. The adjusted R-squared is 0.14.

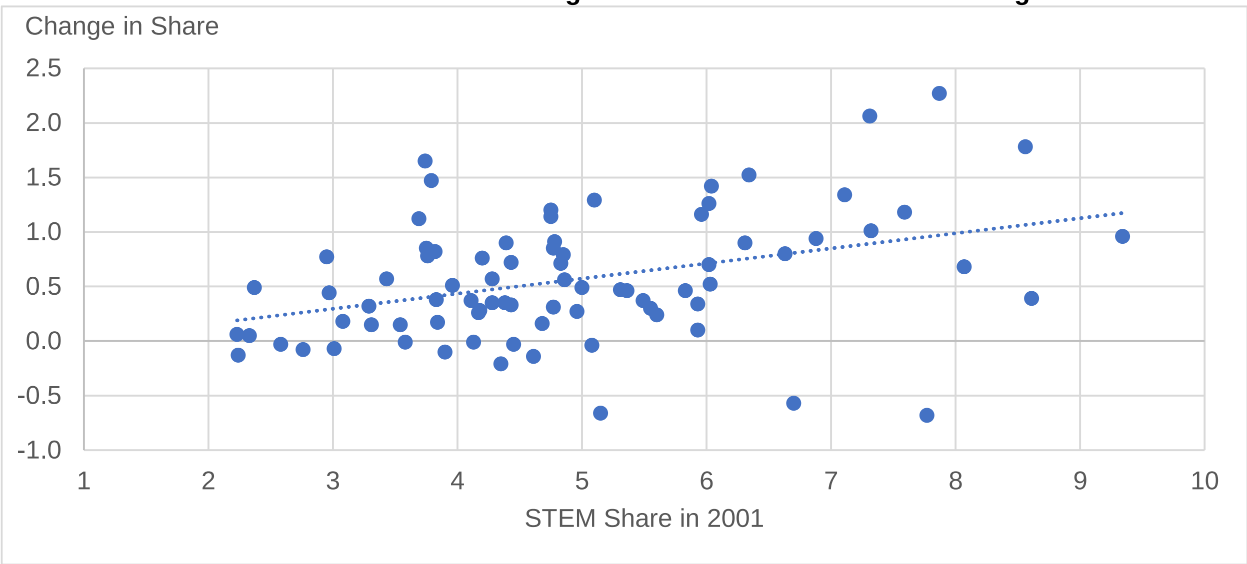
Table 11 shows the metro areas that experienced the largest and smallest increases in the STEM share of employment from 2001 to 2019. The list of "high performers" includes not only the superstar information technology hubs of the San Francisco, San Jose, Seattle, and Boston metro areas but also some fast-climbing high-tech metro areas such as Raleigh and Salt Lake City. Also experiencing large gains in the STEM share were older, more traditional employers of STEM

[19] The sample analyzed consists of the 83 metro areas in Table 2 less the San Jose and Wichita metro areas, which proved to be extreme outliers.

workers such as Metro Detroit and Metro Kansas City. Metro Phoenix experienced a gain in STEM share of only 0.30 percentage points, which was 0.35 points below expectations. Metro Tucson had a gain in the STEM share of 0.46, which was 0.23 percentage points below what would be expected on the basis of its initial STEM share.

CHART 7
DIVERGENCE IN LEVELS OF HUMAN CAPITAL AS MEASURED BY STEM INTENSITY

STEM Share in 2001 and the Change in STEM Share From 2001 Through 2019



Source: Hill et al. (2021).

TABLE 11
PERCENTAGE-POINT CHANGE IN THE STEM SHARE BETWEEN 2001 AND 2019 IN SELECTED METROPOLITAN AREAS

	Change in STEM Share	Regression Residual
High Performers:		
San Francisco-Oakland-Berkeley, CA	2.27	1.30
San Jose-Sunnyvale-Santa Clara, CA	2.06	-0.08
Raleigh-Cary, NC	2.06	1.17
Seattle-Tacoma-Bellevue, WA Pittsburgh, PA	1.78	0.71
Baltimore-Columbia-Towson, MD	1.52	0.76
Salt Lake City, UT	1.42	0.70
Detroit-Warren-Dearborn, MI	1.34	0.48
Kansas City, MO-KS	1.29	0.70
Pittsburgh, PA	1.20	0.66
Boston-Cambridge-Newton, MA-NH	1.18	0.25
Low Performers:		
Colorado Springs, CO	-0.68	-1.64
New Haven-Milford, CT	-0.66	-1.25
Albuquerque, NM	-0.57	-1.38
Los Angeles-Long Beach-Anaheim, CA	-0.04	-0.62
Birmingham-Hoover, AL	-0.03	-0.53
Houston-The Woodlands-Sugar Land, TX	0.10	-0.60
Rochester, NY	0.24	-0.42

Source: Hill et al. (2021) (change in STEM share) and univariate regression presented in Chart 7.

UNDERSTANDING DIFFERENCES IN GROWTH AND PROSPERITY ACROSS 10 SELECTED METROPOLITAN AREAS

Population Growth

Table 12 uses the results from regression 5 in Table 4 to estimate the size of the contributions made by climate, housing supply, and educational attainment to recent population growth in Phoenix, Tucson, and eight other large metro areas in the South and West. The table is set up to explain deviations in growth from the 83-metro-area average. For each individual metro area, the deviation in growth shown in the second data column of the table is the sum of deviations attributed to differences in January temperature, housing supply elasticity, college share from 2005 through 2007, and, to complete the accounting, the unexplained residual from regression 5.[20]

The most important reasons for why these selected metro areas have grown at rates different from the 83-metro-area average are climate and housing supply. Relatively warm winters in the Phoenix and Los Angeles areas are estimated to have contributed 19 percentage points to their population growth over the 2000-to-2018 period. Warm winters were also an important factor in the population growth of the Tucson and Austin metro areas. In Metro Denver, on the other hand, relatively cold January temperatures should have reduced population growth by 6 percentage points.

Flexibility in housing supply, or the lack of it, also has played an important role in the growth patterns of U.S. urban areas. As indicated in Table 12, relatively inflexible housing supplies — by virtue of either geography or policy — reduced population growth in the San Francisco and Los Angeles metro areas by 20 percentage points or more and in Metro Seattle by 12 points. In Metro Austin, on the other hand, relatively elastic housing supply allowed for 18 points more population growth.

The three explanatory variables used in regression 5 do not provide, of course, a complete explanation of each metro area's growth experience. There are very large residuals in some cases. Most striking is the case of Metro Las Vegas, where 29 percentage points of growth are left unexplained. Population growth in the Denver metro area was 15 percentage points greater than can be explained with climate, housing supply, and educational attainment. The stories behind each residual are a matter of conjecture and are to some extent idiosyncratic. Metro Las Vegas may have experienced a large in-migration of households that decided to leave high-priced areas in California. Prospective Metro Denver residents may be willing to put up with the cold winters in exchange for great local skiing opportunities and the beauty of the Colorado Rocky Mountains. Among other metro areas, population growth in New Orleans was 22 percentage points below what was predicted by the regression, a shortfall that most certainly had much to do with Hurricane Katrina.

[20] As a mathematical note of explanation, the difference in the interactive terms in regression 5 between metro area i and the 83-metro area average is written as

$$X^iY^i – XY = (X^i – X)Y + (Y^i – Y)X^i$$

where X is either January temperature or college share and Y is housing supply elasticity. The first term on the right-hand side is the part of the deviation attributed to the difference in January temperature or college share, and the second term is the part attributed to the difference in housing supply elasticity.

TABLE 12
DETERMINANTS OF POPULATION GROWTH FROM 2000 TO 2018 IN SELECTED U.S. METRO AREAS

	Log Change in Population		Deviation From the Metro Average Due to the Difference in:			
Metro Area	**2000 to 2018**	**Deviation From the Metro Average**	**Mean January Temperature**	**House Price Elasticity**	**Share of the Population 25 and Older With At Least a Bachelor's Degree in 2005 Through 2007**	**Regression Residual**
Atlanta	0.326	0.157	0.068	0.067	0.045	-0.023
Austin	0.539	0.370	0.142	0.178	0.083	-0.034
Dallas	0.365	0.196	0.100	0.061	0.013	0.022
Denver	0.301	0.132	-0.064	-0.020	0.066	0.151
Las Vegas	0.471	0.302	0.116	-0.042	-0.061	0.289
Los Angeles	0.070	-0.099	0.193	-0.202	0.011	-0.101
Phoenix	0.395	0.226	0.188	-0.045	-0.011	0.093
San Francisco	0.134	-0.035	0.128	-0.225	0.118	-0.056
Seattle	0.255	0.086	0.057	-0.118	0.064	0.083
Tucson	0.203	0.034	0.163	-0.072	0.014	-0.071

Note: The 83-metro-area average of the log change in population between 2000 and 2018 was 0.169.

Source: Calculations made from regression 5 in Table 4.

Focusing specifically on the two large metro areas in Arizona, population growth in Metro Phoenix between 2000 and 2018 was 23 percentage points faster than the average of the 83 metro areas. Nineteen percentage points of this difference can be attributed to climate. But after adjusting for the moderately growth-limiting effects of housing supply and educational attainment, there are an additional 9 percentage points of growth that are left unexplained. It seems likely that there is some overlap in the stories of the Las Vegas and Phoenix areas. Metro Tucson, on the other hand, had population growth that was similar to the national average despite having January temperatures that should have been worth an additional 16 percentage points of growth. Restrictive housing supply can explain how 7 percentage points of that growth did not materialize. But the negative growth residual suggests that other (unnamed) factors served to reduce Metro Tucson population growth by another 7 percentage points.

Earnings Per Worker

Tables 13 and 14 use regression results from Table 7 to account for 2018 earnings per worker in the 10 metro areas and their deviations from the average of the 82 metro areas (excluding San Jose). In Table 13, earnings per worker is defined as employee compensation per wage and salary worker; in Table 14, earnings per worker is labor income (including proprietors' income) divided by total employment (including the number of proprietors). Conclusions from the two tables are broadly similar. However, because of the particular regressions used in the decompositions (regression 4 in Table 13 and regression 8 in Table 14), educational attainment is more important as a determinant of earnings deviations when earnings are measured as employee compensation, and climate is more important when earnings are measured using labor income.

In line with previous conclusions, the STEM share of employment is the most important factor in determining whether earnings per worker in a particular metro area deviates significantly from the national average. Metro areas with relatively large STEM shares that, in turn, produce above-average earnings per worker include Seattle, San Francisco, Austin, and Denver. At the other extreme, below-average earnings in Metro Las Vegas are to a large extent a consequence of a lack of STEM jobs in the area.

Educational attainment is positively correlated with the STEM share. So, especially in Table 13, which is based on a regression with a relatively large college share coefficient, the metro areas that enjoy relatively high earnings per worker because of a prevalence of STEM jobs in their overall employment also benefit from having a relatively high percent of their populations with college degrees. In the same way, earnings per worker in Metro Las Vegas is dragged down below the national average because of both a low STEM share and a low college share.

The last column in Tables 13 and 14 shows the amount of a metro area's earnings per worker that cannot be explained by levels of human capital and climate. The largest residuals are for the San Francisco and Seattle metro areas. Earnings per worker in these metros is 8-to-10 percent more than what can be explained by the regression in the case of labor income and 5-to-8 percent more when earnings are measured by employee compensation. San Francisco and Seattle, of course, are metro areas with very high STEM shares. Each has a STEM share of a little over 10 percent, as compared with an average of 5.5 percent across all 82 metro areas.

TABLE 13
DETERMINANTS OF REAL COMPENSATION PER WORKER IN 2018 IN SELECTED U.S. METRO AREAS

	Real Compensation Per Worker		Deviation From the Metro Average Due to the Difference in:			
Metro Area	**2018**	**Deviation From the Metro Average**	**Share of the Workforce With At Least a Bachelor's Degree in 2014 Through 2018**	**STEM Share in 2019**	**Mean January Temperature**	**Regression Residual**
Atlanta	$76,274	$6,483	$1,395	$1,513	$-113	$3,688
Austin	74,893	5,103	2,533	4,934	-255	-2,109
Dallas	74,412	4,621	92	1,122	-175	3,581
Denver	75,209	5,418	2,362	3,998	140	-1,082
Las Vegas	64,253	-5,538	-3,145	-3,639	-205	1,452
Los Angeles	68,262	-1,529	64	-595	-353	-645
Phoenix	69,036	-755	-825	536	-344	-121
San Francisco	87,107	17,316	4,337	6,525	-228	6,683
Seattle	82,740	12,949	2,283	6,805	-92	3,954
Tucson	64,544	-5,247	-1,023	1,150	-296	-5,079

Note: The 82-metro-area average (excluding San Jose) of real compensation per worker in 2018 was $69,791.

Source: Calculations made from regression 4 in Table 7.

TABLE 14
DETERMINANTS OF REAL LABOR INCOME PER WORKER IN 2018 IN SELECTED U.S. METRO AREAS

	Real Labor Income Per Worker		Deviation From the Metro Average Due to the Difference in:			
Metro Area	**2018**	**Deviation From the Metro Average**	**Share of the Workforce With At Least a Bachelor's Degree in 2014 Through 2018**	**STEM Share in 2019**	**Mean January Temperature**	**Regression Residual**
Atlanta	$64,361	$2,015	$605	$1,385	$-848	$873
Austin	65,852	3,506	1,098	4,516	-1,911	-197
Dallas	65,571	3,225	40	1,027	-1,307	3,465
Denver	66,835	4,490	1,024	3,660	1,049	-1,243
Las Vegas	54,553	-7,793	-1,364	-3,331	-1,537	-1,561
Los Angeles	58,929	-3,417	28	-545	-2,644	-256
Phoenix	59,082	-3,264	-358	490	-2,572	-824
San Francisco	76,495	14,150	1,881	5,973	-1,710	8,006
Seattle	74,552	12,207	990	6,229	-690	5,678
Tucson	55,764	-6,582	-444	1,053	-2,213	-4,978

Note: The 82-metro-area average (excluding San Jose) of real labor income per worker in 2018 was $62,346.

Source: Calculations made from regression 8 in Table 7.

It is tempting to speculate that the linear regressions used in the earnings analysis do not capture the effect of agglomeration economies — the productivity-enhancing effect of large concentrations of STEM labor. In the standard spatial equilibrium model, agglomeration economies serve to raise productivity and nominal earnings, but not real earnings. Real earnings differentials would be arbitraged away. An alternative explanation more consistent with urban theory is that there are differences in the quality of STEM labor, with quality being especially high in the San Francisco and Seattle areas. Widely available measures of human capital such as the percent of the population with a college degree or the percent of employment in STEM occupations fail to reflect nuanced aspects of human capital, such as type and level of degrees, quality of institutions from which degrees are received, and the particular mix of STEM occupations represented.[21]

Focusing on the two large metro areas in Arizona, real earnings per worker in the Phoenix area is fairly well explained by human capital and climate. The STEM share of employment in Metro Phoenix is a little above the 82-metro-area average (5.9 versus 5.5 percent), while Phoenix's college share of the adult population is below the metro average (34.3-versus-37.5 percent). The two human capital variables are about a wash in explaining deviations in earnings per worker. In Table 14 where mean January temperature is a significant determinant of labor income per worker, the Phoenix area's relatively warm winters serve to reduce earnings per worker by $2,600. This is about how much below the 82-metro-area average real labor income per worker is in the Phoenix area.

Real earnings per worker in Metro Tucson is not as well explained by human capital and climate as in Metro Phoenix. Levels of human capital in the Tucson area are not markedly different from the national average. Metro Tucson's warm winters should serve to significantly lower real earnings, but real earnings are 8-to-9 percent lower than what can be explained by climate and human capital. There are several possible explanations for the Tucson area's large negative earnings residuals. The amenity value of living in Metro Tucson may involve more than just warm winters. Or the quality of human capital in Tucson may be lower than what is represented by the usual education and STEM occupation statistics.

Per Capita Personal Income

Table 15 uses the results from regression 6 in Table 9 to explain differences in real per capita personal income between each of the 10 selected metro areas and the 82-metro-area average. Explanatory variables listed in the table include the human capital and climate variables used to explain earnings per worker, the percent of the population 65 years and older (to help account for differences in nonearnings income per person), and the employment-to-population ratio measured to include proprietors as well as wage and salary workers.

Each variable makes a significant contribution to the accounting:

[21] Empirical support for this explanation comes from Hill et al. (2021). The quality of STEM workers in individual metro areas was measured by summing over the 81 STEM occupations the difference in the share of total STEM employment in a metro area times the national median earnings per job as a ratio to the overall STEM median. Among the 83 metro areas in this study, San Jose ranked first, San Francisco ranked second, and Seattle ranked fourth in 2019 in this measure of STEM job quality.

- High levels of human capital in the San Francisco, Seattle, Austin, and Denver metro areas go a long way toward explaining their high levels of real per capita income. In the case of Metro Las Vegas, low educational attainment and a low share of STEM employment are almost sufficient in themselves to explain why real per capita income is $5,000 below the national average.
- Nine of the 10 metro areas have relatively warm climates. So, most of the entries in the climate column are negative, in amounts ranging from $400 up to $1,500.
- The elderly share of the population is positively related to the nonearnings income component of per capita personal income. All but one of the 10 metros in the table has a relatively young populace. So, this demographic generally serves to reduce per capita income deviations. The metros with the lowest elderly shares are Austin (10.2 percent versus a metro average of 14.6 percent) and Dallas (10.8 percent). Demographics make their per capita incomes about $1,400 lower than the national average. None of the 10 metros has a population as old as the large retirement areas in Florida, but Metro Tucson does have an elderly share (18.7 percent) that exceeds the national average. This contributes $1,400 to the difference between its per capita income and the 82-metro-area average.
- The total employment-to-population variable makes the largest single contribution to explaining differences in real per capita income. The 82-metro-area average employment-to-population ratio is 62.7 percent. Selected metro areas with much higher employment-to-population ratios are San Francisco (72.1 percent), Denver (71.2 percent), and Austin (69.7 percent). These differences explain $3,200 to $4,300 of the deviations in their per capita incomes. The two Arizona metro areas have relatively low employment-to-population ratios (57.5 percent in Phoenix and 50.6 percent in Tucson). This serves to reduce their relative per capita incomes by $2,300 to $5,500.

Table 15 offers the following method of accounting for differences in real per capita personal income between Phoenix, Tucson, and the 82-metro-area average. Metro Phoenix's per capita income is $6,900 below the national average. Favorable climate can explain $1,500 of that gap, and a low employment-to-population ratio can explain another $2,300. But there is $2,900 that cannot be explained by the variables in the model. Metro Tucson's per capita income is $7,500 below the 82-metro-area average. Warm winters explain $1,300 of that gap, and a low employment-to-population ratio contributes another $5,500. However, a relatively large elderly population should make Tucson's per capita income $1,400 higher than the national average. This leaves an overall shortfall of $2,300 that is left unexplained.

TABLE 15
DETERMINANTS OF REAL PER CAPITA PERSONAL INCOME IN 2018 IN SELECTED U.S. METRO AREAS

	Real Per Capita Personal Income		Deviation From the Metro Average Due to the Difference in:					
Metro Area	**2018**	**Deviation From the Metro Average**	**Share of the Population 25 and Older With At Least a Bachelor's Degree in 2014 Through 2018**	**STEM Share in 2019**	**Mean January Temperature**	**Share of the Population 65 and Older in 2014 Through 2018**	**Total Employment -to- Population Ratio in 2018**	**Regression Residual**
Atlanta	$54,664	$319	$1,224	$553	$-488	$-1,079	$1,182	$-1,072
Austin	59,519	5,174	2,679	1,804	-1,101	-1,534	3,239	88
Dallas	56,469	2,124	413	410	-753	-1,324	2,548	831
Denver	61,668	7,324	2,440	1,462	605	-800	3,930	-314
Las Vegas	49,338	-5,007	-2,377	-1,331	-886	-170	-825	582
Los Angeles	54,557	212	246	-218	-1,523	-520	1,902	325
Phoenix	47,440	-6,904	-446	196	-1,482	110	-2,349	-2,933
San Francisco	76,167	21,822	3,824	2,386	-985	75	4,339	12,185
Seattle	66,267	11,922	2,226	2,488	-397	-625	2,372	5,858
Tucson	46,874	-7,470	-183	420	-1,275	1,438	-5,529	-2,342

Note: The 82-metro-area average (excluding San Jose) of real per capita personal income in 2018 was $54,345.

Source: Calculations made from regression 6 in Table 9.

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