STEM ECONOMIC ACTIVITY IN ARIZONA

February 2021

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P3 | PRODUCTIVITY AND PROSPERITY PROJECT

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

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A Report from the Productivity and Prosperity Project (P3), Supported by the Office of the University Economist

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TABLE OF CONTENTS

Executive Summary	1
Summary	2
Determinants of Growth and Prosperity in U.S. Metro Areas	12
Determinants of Urban Population Growth: Climate, Housing Supply, and Human Capital	12
Explaining Differences in Earnings and Incomes Across Metropolitan Areas	17
Understanding Differences in Growth and Prosperity Across 10 Selected Metro Areas	24
Recent Divergence in Levels of Human Capital Across Metropolitan Areas	31
Setting Aspirational Goals	34
STEM Employment and Earnings	43
Introduction	43
STEM Economic Activity in the United States	48
STEM Economic Activity by State	54
STEM Economic Activity in Arizona	58
STEM Economic Activity by Metro Area	70
Arizona's Metropolitan and Nonmetropolitan Areas	76
Geographic Variations in STEM Economic Activity	95
Other STEM Indicators for Arizona and the Nation	99
Human Capital	99
Financial Capital	102
Economic Impacts of STEM Economic Activities in Arizona	111
Current Impacts	111
Impacts Had Arizona Not Disproportionately Lost STEM Jobs	112
Impacts From Expanding the STEM Presence in Arizona	113
References	117
Appendix A: STEM Occupations	120
Appendix B: STEM Industries	122
Appendix C: The REMI Model	124

LIST OF TABLES

1.	Regression Analysis of Population Growth Between 2000 and 2018 in 83 Metropolitan Areas	15
2.	Regression Analysis of Real Earnings Per Worker in 2018	19
3.	Regression Analysis of Real Earnings Per Capita in 2018	22
4.	Regression Analysis of Real Per Capita Personal Income in 2018	23
5.	Determinants of Population Growth From 2000 to 2018 in Selected U.S. Metro Areas	25
6.	Determinants of Real Compensation Per Worker in 2018 in Selected U.S. Metro Areas	27
7.	Determinants of Real Per Capita Personal Income in 2018 in Selected U.S. Metro Areas	30
8.	Percentage-Point Change in Educational Attainment Between 2005 Through 2007 and 2014 Through 2018 in Selected Metropolitan Areas	33
9.	Percentage-Point Change in STEM Share Between 2001 and 2019 in Selected Metropolitan Areas	35
10.	53 Largest Metropolitan Areas Ranked by Human Capital: Variable Rank and Value	36
11.	Top-10 Metropolitan Areas Based on Human Capital: Variable Values and Ranks Among 53 Largest Metropolitan Areas	39
12.	Second-10 Metropolitan Areas Based on Human Capital: Variable Values and Ranks Among 53 Largest Metropolitan Areas	41
13.	STEM Employment and Aggregate Earnings in The United States	50
14.	Earnings Per Job in the United States and Arizona	51
15.	Occupational STEM Share of Employment by State	56
16.	STEM Employment and Aggregate Earnings in Arizona	60
17.	STEM Aggregate Earnings by Occupation in Metropolitan Areas by Size Class	73
18.	STEM Employment by Occupation in Metropolitan Areas by Size Class	74
19.	STEM Aggregate Earnings by Industry in Metropolitan Areas by Size Class	75
20.	STEM Aggregate Earnings in Arizona's Metropolitan Areas	77
21.	STEM Aggregate Earnings by Occupational Category in Arizona's Metropolitan Areas	78
22.	STEM Aggregate Earnings by Industrial Category in Arizona's Metropolitan Areas	81
23.	STEM Share of Aggregate Earnings in Arizona's Metropolitan and Nonmetropolitan Areas	94
24.	Economic Impacts of STEM Workers, Arizona, 2019	112
25.	Economic Impact of Maintaining STEM Share of Employment in Arizona Relative to the National Average, 2019	113
26.	Economic Impact of Maintaining Share of Employment in Arizona Relative to the National Average in Computer and Electronic Product Manufacturing and in Aerospace Product and Parts Manufacturing, 2019	114
27.	Economic Impact of Adding 1,000 STEM Workers Per Year in Arizona From 2021 Through 2030	114
28.	Economic Impact of Adding 1,000 STEM Workers Per Year in Specific Industries in Arizona From 2021 Through 2030	115
29.	Economic Impact of Private-Sector Investment in STEM Activities of $1 Billion Per Year in Arizona From 2021 Through 2030	116

LIST OF CHARTS

1.	Population Growth Between 2000 and 2018 and Educational Attainment in 83 Metropolitan Areas	18
2.	Divergence in Levels of Human Capital as Measured by Educational Attainment	32
3.	Divergence in Levels of Human Capital as Measured by STEM Intensity	34
4.	STEM Employment and Aggregate Earnings as a Share of Total Employment and Aggregate Earnings in Arizona and the United States	68
5.	STEM Aggregate Earnings by Category as a Share of Total Aggregate Earnings in Arizona and the United States	69
6.	Inflation-Adjusted Earnings Per Job in Arizona and The United States	71
7.	Number in Science, Engineering, and Health Fields Per 1 Million Residents in Arizona and the United States	100
8.	Number of Employed Doctoral Scientists and Engineers Per 1 Million Residents in Arizona and the United States	101
9.	Number of Patents Granted Per 1 Million Residents in Arizona and the United States	103
10.	Research and Development Funding Per $1 Million of Gross Domestic Product in Arizona and the United States	104
11.	Academic Research and Development Funding by Source Per $1 Million of Gross Domestic Product in Arizona and the United States	105
12.	Innovation Grants in Arizona and the United States	107
13.	Venture Capital in Arizona and the United States	109

EXECUTIVE SUMMARY

Human capital, as measured by educational attainment — particularly the percent of the population/workforce with at least a bachelor's degree — and the share of the workforce engaged in STEM (science, technology, engineering, and math) activities, are important factors explaining the growth and prosperity of states and metropolitan areas. Educational attainment does better than the STEM share in explaining the population growth and per capita income of an area, but the STEM share is better than educational attainment in explaining earnings per worker.

As documented previously,[1] educational attainment in Arizona historically exceeded the national average, but has declined relative to the nation since 1970 and is now below average. Historical data on the STEM share of the economy are more limited, but the STEM share has declined relative to the nation since 1990, falling from above average to average. Arizona is now a second-tier STEM state, ranking above the median state but with a STEM share of the economy no higher than the U.S. average.

STEM occupations can be divided into six categories. In 2019, Arizona's share in the computer and engineering technician categories was above the national average and the share in the math category was average. However, Arizona's share in the science category was considerably below average, ranking near the bottom of the states. Arizona's share also was below average in the science technician and engineering categories. The change in share between 2005 and 2019 in Arizona outpaced the U.S. average in the computer and math categories and was near average in the science technician category. Arizona's change was below average in the other categories, ranking among the bottom four states in the engineering and engineering technician categories.

In Metro Phoenix, STEM activity as a share of the total economy in 2019 was below the norm of large metro areas. Metro Phoenix is primarily responsible for the state's mediocre performance. The share in Metro Phoenix was below the norm of large metro areas in the computer, engineering, science (last in rank), and science technician categories. In contrast, the STEM share in Metro Tucson considerably exceeded the norm of moderately large metro areas, due to high shares in the computer, engineering, and science categories.

The change between 2005 and 2019 in the STEM share in Metro Phoenix was below the average of large metro areas, with considerable weakness in the engineering, engineering technician, and science categories. The change in Metro Tucson was a bit below the average of moderately large metro areas, as gains in the computer and science categories were offset by losses in the engineering and engineering technician categories.

An effort to improve Arizona's human capital would result in considerable gains in the state's productivity and prosperity. Those working in STEM occupations are highly skilled and earn substantially more than other workers. They are disproportionately engaged in traded activities, selling their goods and services to customers outside of Arizona, thereby bringing money into Arizona and driving the economy. STEM activities have a strong multiplier effect, with each STEM job supporting 2.75 other jobs.

[1] For example, see the September 2018 paper "The Relationship Between Government Finance, Educational Attainment, and Economic Performance," https://wpcarey.asu.edu/sites/default/files/taxeducecon09-18.pdf .

SUMMARY

Economic activities closely associated with STEM — science, technology, engineering, and mathematics — are the focus of this paper. STEM essentially is synonymous with "high technology." However, prior to examining the empirical STEM data, STEM's role in explaining the growth and prosperity of metropolitan areas is examined.

Determinants of Growth and Prosperity in U.S. Metro Areas

This section is based on a review of the literature in urban economics and economic geography as well as regression analyses using recent data.

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.

Ed Glaeser, Enrico Moretti, and others have argued that metro-area differences in the degree to which housing supply responds to demand, 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. 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.

Regression Analyses

Initial levels of human capital in an area 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 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 Tucson over the period from 2000 to 2018 was similar to the 83-metro-area average, 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 (cost-of-living-adjusted) 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 the 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 $8,200 higher than it is in Phoenix.

Regression results are also reported for a model that explains real earnings per capita in terms of college graduates as a percent of the population, STEM employment as a percent of the population, and mean January temperature. In this analysis, each measure of human capital is statistically significant. Educational attainment may have more of an impact on metro-level earnings per capita than it does on earnings per worker because of a positive correlation between educational attainment and the percent of the population that is employed.

STEM employment as a percent of the population is found to be positively related not only to total real earnings per capita but also to the real earnings of workers in non-STEM occupations.

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 or older. 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. 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 is 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 an 82-metro-area average (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 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.

Recent Divergence in Levels of Human Capital Across Metropolitan Areas
Contributing to the recent divergence of productivity and per capita income across U.S. metro area 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 was 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 a 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.

Setting Aspirational Goals
Highly ranked metro areas based on human capital generally rank highly on prosperity. Among the 53 metro areas with a population of at least 1 million in 2019, Metro Phoenix ranked 41st on the average of two human capital measures: the number aged 25 to 64 with a bachelor's degree or higher as a share of the entire population and STEM employment as a share of the total population. Metro Phoenix ranked 49th on the average of two prosperity measures: per capita personal income and per capita wages and salaries. Metro Tucson ranked 45th in human capital and 52nd in prosperity. The low ranks are in part attributable to Arizona's attractive climate. A substantial improvement in human capital in the Phoenix and Tucson areas would yield considerable gains in prosperity.

A reasonable goal might be for the Phoenix and Tucson areas to match the average of the 11th-through-20th-ranked areas among the 53 large metro areas on human capital. To match the average of the second-10 metro areas on the educational attainment variable, a 5.1 percentage-point (33 percent) increase is needed in Metro Phoenix and a 6.1 percentage-point (42 percent) increase is needed in Metro Tucson. Increases in STEM workers per capita would need to be 0.83 percentage points (a 29 percent increase) in Metro Phoenix and 1.02 percentage points (a gain of 39 percent) in Metro Tucson to move the metro areas to the average of the second 10.

The potential reward from raising human capital in terms of prosperity is significant. The second-10 average for personal income per capita is more than $10,000 higher than in either

Metro Phoenix or Metro Tucson with, at most, only about $4,000 likely explained by climate. Similarly, average wage and salary earnings per capita is nearly $10,000 higher than in Metro Phoenix and nearly $16,000 higher than in Metro Tucson. The second-10 average of non-STEM earnings per capita is $4,100 higher than in Metro Phoenix and $7,200 more than in Metro Tucson.

STEM Employment and Earnings in Arizona

STEM economic activity is measured in two ways: employment and aggregate earnings (the latter is calculated as employment times average earnings per job). Two estimates of employment and aggregate earnings are utilized, one based on occupational data, the other based on industrial data. Conceptually, it is far superior to define STEM by occupation than by industry, but most prior efforts to measure STEM or high technology have utilized industrial data due to its greater availability and more reliable nature.

State of Arizona

In general, Arizona is a second-tier state based on STEM's share of total economic activity, ranking above the median state but with a share similar to the national average.

Occupational Data, 2019. Arizona's STEM share of employment in 2019 was 5.62 percent, slightly greater than the national average of 5.51 percent, ranking 16th among the 51 "states" including the District of Columbia. Arizona's STEM share of aggregate earnings in 2019 was 10.08 percent, slightly less than the national average of 10.18 percent, ranking 18th among the states. Arizona did not compare as favorably relative to a set of 10 western states: Arizona, California, Colorado, Idaho, Nevada, New Mexico, Oregon, Texas, Utah, and Washington. In 2019, Arizona ranked sixth among these 10 states on the STEM share of employment and seventh on the STEM share of aggregate earnings.

Arizona also compares less favorably based on the difference between its actual STEM share of employment and an "expected share." The expected share is calculated based on each metropolitan area of the state and the state's nonmetropolitan area having a STEM employment share equal to the national average of like-sized areas. Based on occupational employment, Arizona's actual STEM share in 2019 was less than the expected value, ranking 36th on the differential. Arizona ranked ninth among the western states on the differential between the actual and expected share in 2019, besting only Nevada. Texas was the only other western state to have an actual value less than expected.

The 81 STEM occupations can be divided into six categories. In 2019, based on both employment and aggregate earnings, Arizona's STEM share was greater than the national average in the computer and engineering technician categories and near average in the math category. The share was below average in the engineering, science, and science technician categories, ranking near the bottom of the western states in each of these categories and near the bottom of all states in the science category.

Occupational Data, 2005 to 2019. The change between 2005 and 2019 in the occupational STEM employment share of 0.81 percentage points in Arizona was marginally less than the national average of 0.83 percentage points. The differential was larger based on aggregate earnings: a gain of 1.45 percentage points in Arizona and 1.70 points in the nation. Arizona ranked 20th among all states and in the middle of the western states on each measure.

The actual change in share between 2005 and 2019 in Arizona was less than expected, ranking 27th. Arizona ranked sixth among the western states on the differential between the actual and expected change, ahead of Texas, New Mexico, Idaho, and Nevada. The actual change exceeded the expected change in the other five western states.

Arizona's change in STEM share between 2005 and 2019 exceeded the national average only in the computer and math categories. The changes in the engineering and engineering technician categories were the worst among the western states and ranked in the bottom four among all states.

Industrial Data, 2019. Based on industrial data, Arizona's STEM employment share in 2019 of 5.32 percent exceeded the national average of 4.81 percent and ranked 13th among all states, though only seventh among the western states. The STEM aggregate earnings share in Arizona of 10.06 percent was not much higher than the national average of 9.89 percent. Arizona ranked 11th among all states but only seventh among the western states.

The 57 STEM industries can be placed into two categories — manufacturing and services. Arizona's share in the manufacturing category in 2019 was considerably higher than the national average, ranking among the top six states nationally, but only among the top four western states. In the services category, Arizona's share was considerably below average, but ranked above the median of all states.

Industrial Data, 2001 to 2019. The change in STEM share based on the industrial data was considerably inferior in Arizona than the nation. The employment share dropped 0.62 percentage points in Arizona, compared to a gain of 0.18 points nationally. The aggregate earnings share fell 0.89 percentage points in Arizona but rose 1.44 points nationally. On each measure, Arizona ranked among the bottom 10 states nationally and among the bottom three of the western states.

Each category, but especially manufacturing, performed poorly in Arizona relative to the nation between 2001 and 2019. Arizona ranked among the bottom four states in the manufacturing category. Despite the below-average change, Arizona ranked among the top 15 states in the services category.

Two STEM manufacturing activities are of primary significance in Arizona: electronics and aerospace. Electronics is dominated by the "semiconductor and related device manufacturing" industry. Between 2001 and 2019, this industry's share fell 1.48 percentage points in Arizona compared to a decline nationally of only 0.12 percentage points. Arizona's change ranked 50th nationally and last among the western states. Despite this, in 2019, Arizona's semiconductor share of 1.68 percent was far above the national average of 0.32 percent, ranking third nationally and among the western states.

Aerospace manufacturing can be divided into two parts: three aircraft manufacturing industries and three guided missile and space vehicle industries. In 2019, Arizona's share in each part was considerably higher than the national average, with Arizona ranking among the leading states in each. However, the two parts diverged on the change in share between 2001 and 2019. The sum of the three guided missile and space vehicle industries experienced an increase in share in Arizona compared to a slight gain nationally. Arizona ranked in the top 10 nationally and in the top three of the western states. In contrast, the sum of the three aircraft industries experienced a much larger decrease in share in Arizona (0.40 percentage points) than the nation (0.03 percentage points). Arizona ranked in the bottom five nationally and in the bottom three of the western states.

Arizona's Metropolitan and Nonmetropolitan Areas

Seven metro areas, covering eight counties, are present in Arizona. The state's other seven counties have been combined into one nonmetropolitan area.

Due to a positive relationship between metro area size and STEM share, the nation's 384 metro areas are divided into six size classes based on the number of workers in 2019. Metro Phoenix is in the largest size class, consisting of 36 metro areas with employment of at least 1 million. Metro Tucson is in the second-largest size class, consisting of 45 metro areas with employment of between 350,000 and 999,999. Metro Prescott and Metro Yuma are in the second-smallest size class, consisting of 71 metro areas with employment of between 75,000 and 124,999. The Flagstaff, Lake Havasu City, and Sierra Vista metro areas are in the smallest size class of 124 metro areas with employment of less than 75,000. In the following discussion, each of Arizona's metro areas are compared to the size-class average.

Metro Phoenix was primarily responsible for the state's actual STEM share being less than the expected share in 2019 (based on occupational employment). Metro Phoenix dominates the state, accounting for 72 percent of the state's employment in 2019, and had a STEM share 0.59 percentage points lower than its size-class average. In contrast, Metro Tucson's 2019 STEM share was 0.89 percentage points greater than the average of its size class, but only 13 percent of the state's employment was located in Metro Tucson. The balance of the state had a small net negative effect on the state's actual STEM share relative to the expected share.

The somewhat lesser increase between 2005 and 2019 in Arizona's actual occupational employment STEM share versus the expected change in share primarily was due to the poor performance outside the two major metro areas, but Metro Phoenix also contributed.

Metro Phoenix. The overall aggregate earnings STEM share in 2019 in Metro Phoenix was less than its size-class average based on both the occupational and industrial data. Metro Phoenix ranked below the middle of the size class using the occupational data but above the middle using the industrial data. The occupational STEM share in Metro Phoenix exceeded the size-class average by more than a marginal amount only in the engineering technician category; Metro Phoenix ranked last in the science category and near the bottom in the science technician category. While the STEM share was above the size-class average in the industrial manufacturing category, it was considerably below average in the services category.

The occupational STEM share rose between 2005 and 2019 in Metro Phoenix, but by less than the size-class average. Metro Phoenix performed well in the computer and math categories, but ranked near the bottom in the engineering and engineering technician categories. The industrial STEM share fell between 2001 and 2019 in Metro Phoenix, compared to a gain in the size-class average; Metro Phoenix ranked in the bottom 10 percent. The decline in the manufacturing category and the increase in the services category each was inferior to the size-class average, with Metro Phoenix ranking near the bottom in manufacturing.

The largest STEM industry in Metro Phoenix in 2019 was "semiconductor and related device manufacturing," whose share ranked ninth in the nation and accounted for more than one-fifth of the metro area's industrial STEM total. However, between 2001 and 2019, the share in this industry fell considerably, with Metro Phoenix ranking among the bottom 10 metro areas in the country.

Metro Tucson. The overall aggregate earnings STEM share in 2019 in Metro Tucson was greater than its size-class average based on both the occupational and industrial data, with a large differential industrially. Metro Tucson ranked in the top 20 percent of its size class using the occupational data and in the top 10 percent using the industrial data. The occupational STEM share in Metro Tucson exceeded the size-class average in the computer, engineering, and science categories, but ranked below the middle of the size class in the math and science technician categories. The industrial STEM share was far above the size-class average in the manufacturing category, ranking in the top 5 percent. The share in the services category was below the size-class average but ranked above the middle of the 45 metro areas.

The occupational STEM share rose slightly less than the size-class average between 2005 and 2019 in Metro Tucson. The Tucson area outpaced the size-class average in the computer and science categories, but performed poorly in the engineering, engineering technician, and science technician categories. The industrial STEM share fell between 2001 and 2019 in Metro Tucson by more than the size-class average. The decline in the manufacturing category and the increase in the services category each was inferior to the size-class average.

More than half of the industrial STEM activity in Metro Tucson in 2019 was in one industry — "guided missile and space vehicle manufacturing" — in which Metro Tucson ranked first in the nation. This industry's change in share between 2001 and 2019 also led the nation.

Other Metro Areas. The Prescott and Yuma metro areas are among the 71 metro areas with employment of between 75,000 and 124,999 in 2019. The overall occupational and industrial STEM shares in 2019 in each were less than the size-class average. Metro Prescott's share was less than the size-class average in each occupational category, ranking near the bottom in the computer and math categories. The share also was below average in the industrial services category. Metro Yuma's share was below the size-class average in the occupational computer, engineering, and science categories and in the industrial manufacturing category.

The change in the overall STEM share — both occupationally and industrially —exceeded the size-class average in Metro Yuma. In each category except occupational computer, Metro Yuma's change at least equaled the size-class average. Metro Yuma ranked in the top 10 percent in the change in the occupational engineering technician and industrial services categories. Metro Prescott also had a change in the overall industrial STEM share in excess of the size-class average, due to the manufacturing category. However, the overall change in occupational STEM share was less than the size-class average, with a subpar change in each category except computer.

The Flagstaff, Lake Havasu City, and Sierra Vista metro areas are among the 124 metro areas with employment of less than 75,000 in 2019. The overall STEM share in 2019 and the change in share was below the size-class average in the Flagstaff and Lake Havasu City metro areas, both occupationally and industrially. Metro Flagstaff's share in 2019 was above average, but the change in share was subpar, in the science and science technician categories. In Metro Lake Havasu City, the 2019 share was less than the size-class average in every category and ranked near the bottom in most. The change in share was below average in each category except industrial manufacturing.

In contrast, Metro Sierra Vista ranked fourth in the size class in the overall occupational STEM share, and 10th in the overall industrial share, in 2019. The share was above average in each category except occupational science and industrial manufacturing. The overall change in share both occupationally and industrially also exceeded the size-class average. The occupational computer and industrial services categories had large gains in share.

Other STEM Indicators for Arizona

Arizona generally compares unfavorably to the nation on other indicators related to STEM and to innovation. The indicators are divided into two types: human capital and financial capital.

Arizona compares unfavorably on each of the human capital indicators, with a flat or negative trend in recent years:

- Per capita number of graduate students in science, engineering, and health fields: Into the early 1990s, Arizona's per capita number had been higher than the national average. In 2018, the latest data, Arizona's figure was 14 percent below average.
- Per capita number of postdoctorates in science, engineering, and health fields: Into the mid-1980s, Arizona's per capita number had been similar to the national average. In 2018, the latest data, Arizona's figure was 39 percent below average.
- Per capita number of employed doctoral scientists and engineers: Arizona has been consistently below the national average. In 2017, the latest data, Arizona's per capita number was 31 percent below average.
- Per capita number of employed doctoral scientists and engineers in science and engineering occupations: Arizona has been consistently below the national average. In 2017, the latest data, Arizona's per capita number was 33 percent below average.
- Per capita number of patents: Arizona's per capita number was similar to the national average from the late 1970s into the late 2000s. In 2019, the latest data, Arizona's figure was 22 percent below average.

Arizona's comparison to the nation is mixed on the financial capital indicators:

- Industry research and development (R&D) spending relative to gross domestic product (GDP): After two decades of subpar figures, Arizona's value has been similar to the national average since 2008. In 2017, the latest data, Arizona's value was 6 percent below average.

- Academic R&D spending relative to GDP: Academic R&D spending nationally is about one-fifth the magnitude of industry R&D. Arizona's value has fluctuated from higher to lower than the national average. In 2018, the latest data, Arizona's value was 1 percent higher. Arizona compares favorably on academic R&D derived from institutional and miscellaneous sources, but unfavorably from federal, state and local government, and industry sources.
- Innovation grants relative to GDP: The U.S. Small Business Administration has two types of innovation grants. Arizona's value in the Small Business Innovation Research program has fluctuated from higher to lower than the national average. In 2017, the latest data, Arizona's value was 7 percent lower. Arizona also has varied over time relative to the U.S. average in the much smaller Small Business Technology Transfer program. In 2017, the latest data, Arizona's value was 40 percent higher.
- Venture capital relative to GDP: Arizona's value has consistently been much lower than the national average. In 2019, the latest data, Arizona's value was 85 percent lower.

Economic Impacts of STEM Economic Activities in Arizona

Based on the industrial definition, STEM activities predominantly are "traded" economic activities — those whose products and services are sold to customers outside the local region. The sale of goods and services to customers from outside the region imports money into the regional economy that would otherwise not be present. In contrast to traded activities, nontraded (or "local") economic activities are location specific since they sell their goods and services to regional customers. While an integral part of a regional economy, nontraded activities do not import money into the regional economy. Their presence in the region is due to traded activities — the expenditures made locally by companies selling traded goods and services and by the employees of these businesses. In this way, traded activities "drive" the regional economy while nontraded activities respond to the growth occurring in traded activities.

A disproportionate share of those working in STEM occupations are employed by companies that export their products and services. Moreover, earnings per job in STEM activities are much higher than average. Thus, STEM activities have a strong economic impact.

During 2019 based on industrial data, the presence of STEM workers in Arizona generated economic impacts of $74.5 billion in GDP, $53.3 billion in earnings, and $4.5 billion in state and local government tax payments. The 172,621 STEM workers supported an additional 474,050 workers, for a total employment impact of 646,671 jobs in all sectors of the economy. To put it in perspective, these impacts represent 19.9 percent of Arizona's total employment and 20.1 percent of Arizona's GDP.

Since 1990, Arizona has experienced disproportionate job losses in in computer and electronic product manufacturing and, to a lesser extent, in aerospace product and parts manufacturing. STEM industrial employment in Arizona in 2019 would have been 53,100 higher had Arizona's share in computer and electronic product manufacturing and aerospace product and parts manufacturing not declined versus the nation since 1990. Had this disproportionate loss of jobs not occurred in Arizona, in 2019 the state's GDP would have been $27.4 billion higher, with earnings $18.5 billion higher, tax payments $1.6 billion higher, and 206,558 more jobs in all sectors. Employment would have been 6.4 percent higher and GDP would have been 7.4 percent higher.

If Arizona were to add 1,000 STEM workers each year for the next 10 years — beyond the gains of the baseline forecast — resulting in an additional 10,000 STEM workers in the state in 2030, the cumulative impact of these additional STEM workers on Arizona's economy during the 10-year time period would be a gain of $28.2 billion in GDP, an increase of $18.3 billion in earnings, a rise of nearly $1.6 billion in tax payments, and an increase of 214,746 in total job years in Arizona.

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

This chapter 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, the report also provides an empirical update using data on population growth from 2000 to 2018 and data for 2018 on real[2] earnings per worker, real earnings per capita, and real per capita personal income. The newly estimated models are used to assess the economic performance of the Phoenix and Tucson metro areas.

Determinants of Urban Population Growth: Climate, Housing Supply, and Human Capital

Climate

Over the past 50 years, the U.S. population has steadily shifted from the Midwest and Northeast to the West and the South. Over the period from 1970 to 2018, the shares of the national population living in the Midwest and Northeast have each declined by 7 percentage points. The share of the population living in the West, on the other hand, has increased by 6½ percentage points, and the share residing in the South has increased by 7½ points.

Many economists have weighed in on the underlying factors behind the movement of people and jobs to the West and South.[3] One group of explanations 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.

Another group of explanations 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 pro-business culture of the South has been aided by low unionism and right-to-work laws.

Given the regional pattern of U.S. population growth in the period since 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

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[2] "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.

[3] 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.

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 other economic variable including metro-level educational attainment, population density, availability of public transportation, and historical importance of manufacturing in the local economy.

Housing Supply

When thinking about metro areas, population, housing prices, and incomes must be considered together. Housing supply elasticity[4] will determine whether urban success reveals itself in the form of population growth or growth 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 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 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.

Human Capital

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 (see, for example, Glaeser and Shapiro 2003 and Glaeser and Saiz 2003). 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

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[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.

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.[5]

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[6] database from the 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 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.

Regression Analysis

Table 1 provides a selected summary of a multiple regression analysis[7] by Hill (2021) of the determinants of population growth in U.S. metro areas over the period from 2000 to 2018. Explanatory variables used to explain variations in population growth across urban areas are mean January temperature, estimates from Saiz (2010) of the price elasticity of housing supply, and two measures of initial human capital: the percent of the adult population with a bachelor's degree or higher and the percent of employment in STEM occupations.[8] The sample consists of 83 metropolitan areas with a population in 2000 of at least 250,000 people for which an estimate of the elasticity of housing supply is available from Saiz.

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[5] 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).

[6] The Occupational Information Network (O*NET) is a free online database that contains hundreds of occupational definitions (https://www.dol.gov/agencies/eta/onet).

[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."

[8] STEM employment was calculated from BLS data on employment by occupation. There are 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. This is explained in detail in the "STEM Employment and Earnings" chapter of this paper.

TABLE 1
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**	**Regression 4**
Mean January Temperature	0.0084***	0.0077***	0.0085***	
	(0.0011)	(0.0011)	(0.0011)	
Elasticity of Housing Supply	0.044***	0.037***	0.044***	-0.261***
	(0.013)	(0.013)	(0.013)	(0.033)
Mean January Temperature Times The Elasticity of Housing Supply				0.0052***
				(0.0006)
Educational Attainment, 2005 Through 2007^^	0.0066***		0.0082***	
	(0.0020)		(0.0031)	
Educational Attainment Times The Elasticity of Housing Supply				0.0042***
				(0.0009)
STEM Share of Employment in 2001		0.013**	-0.0062	
		(0.0063)	(0.0096)	
Constant	-0.423***	-0.264***	-0.442***	0.073***
	(0.090)	(0.068)	(0.095)	(0.025)
Adjusted R-Squared	0.410	0.361	0.406	0.536

(continued)

TABLE 1 (continued)
REGRESSION ANALYSIS OF POPULATION GROWTH BETWEEN 2000 AND 2018 IN 83 METROPOLITAN AREAS

^ 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.
^^ 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).

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.

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 the independent variables in a regression model.

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).

In regression 1, the explanatory variables are climate, housing supply, and educational attainment. All coefficients have the expected sign, and all are significant at the 99 percent level of confidence. The three explanatory variables together explain 41 percent of the variation in population growth across the 83 metro areas.

Regression 2 is similar to regression 1 except that the STEM share of employment is used rather than educational attainment as a measure of human capital. The coefficient on the STEM variable is statistically significant at the 95 percent level of confidence. However, the initial STEM share of employment is not quite as good a predictor of future metro area population growth as the initial college share in the population. The adjusted R-squared falls from 0.41 to 0.36 when the STEM share of employment replaces educational attainment in the regression. The coefficients and t-values[9] of the January temperature and housing supply variables are also lower in the STEM regression.

Regression 3 shows what happens when both educational attainment and the STEM share of employment are included in the regression. The coefficient of the STEM share has the wrong sign, although it is statistically insignificant. The adjusted R-squared is slightly lower than it was in the regression with only educational attainment.

In regression 4, the climate and education variables are included interactively with (multiplied by) the elasticity of housing supply. The rationale for this specification is 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 4 is the highest among all the regressions with a value of 0.54. When evaluated using the mean housing supply elasticity of 1.93, regression 4 indicates that a 10-percentage point increase in mean January temperature increases metro population growth between 2000 and 2018 by 10.0 percentage points, and a 10-percentage point increase in the initial educational attainment increases metro population growth by 8.2 percentage points.

The positive association between initial educational attainment and metro area population growth can be seen in the scatter plot shown in Chart 1. In this figure, population growth in a metro area is adjusted for the effects predicted from regression 4 of the deviation in the area's January temperature from the sample mean January temperature of 38.2 degrees and the deviation in the area's housing supply elasticity from the sample mean elasticity of 1.93.

Explaining Differences in Earnings and Incomes Across Metropolitan Areas

Earnings Per Worker

If workers/households are mobile and move to arbitrage differences in utilities[10] across locations, then differences in average real earnings between areas should reflect differences in human

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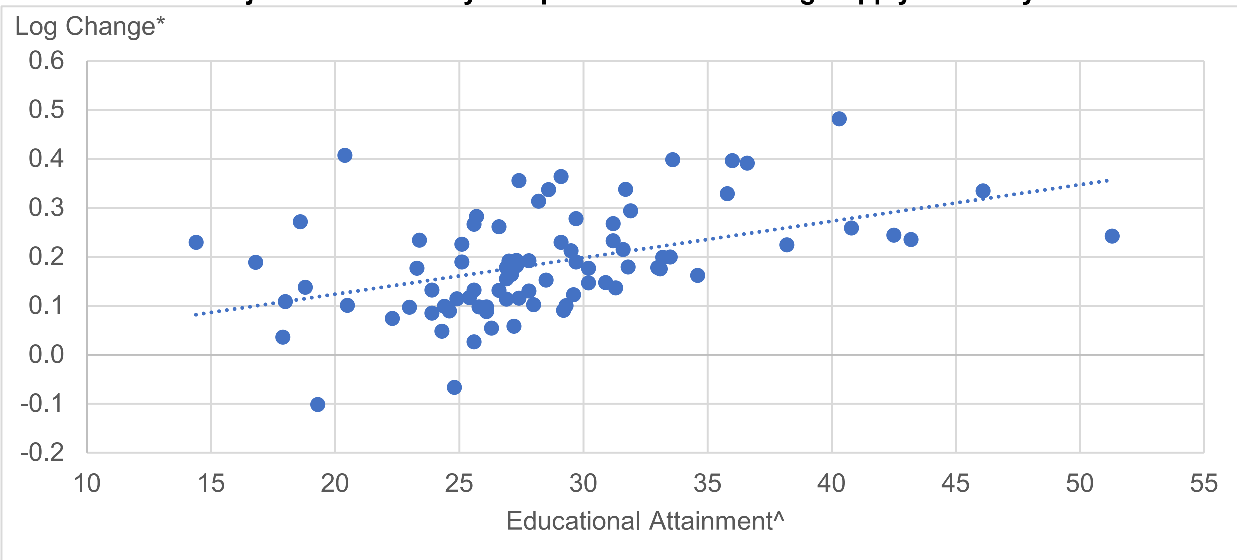
[9] The t-statistic is the ratio of the departure of the estimated value of a parameter from its hypothesized value to its standard error. It is used in hypothesis testing via Student's t-test. In the tables of regression results, the significance of an independent variable is determined from its t-value.

[10] 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.

CHART 1
POPULATION GROWTH BETWEEN 2000 AND 2018 AND EDUCATIONAL ATTAINMENT IN 83 METROPOLITAN AREAS

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



^ 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).

capital and compensate for differentials in urban amenities, with real earnings being lower in areas with greater amenities. Table 2 shows the results of a regression analysis by Hill (2021) 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[11] variable). Human capital levels are measured in two ways: as the percent of the labor force with at least a bachelor's degree and as the percent of those employed who work in STEM occupations.

Earnings per worker are measured as employee compensation (the sum of wages, salaries, and benefits) divided by the number of wage and salary workers. Average earnings in a metro area are adjusted for differences in 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

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

TABLE 2
REGRESSION ANALYSIS OF REAL EARNINGS PER WORKER IN 2018

Dependent Variable: Real Compensation Per Worker^

Independent Variable	**Regression 1**	**Regression 2**	**Regression 3**	**Regression 4**
Workforce Educational Attainment, 2014 to 2018^^	-25.0	54.4	70.6	258.5**
	(81.2)	(79.5)	(106.5)	(103.8)
STEM Share of Total Employment, 2019	2,394.2***	1,826.2***	2,565.1***	1,396.2***
	(272.7)	(291.9)	(333.0)	(392.8)
Mean January Temperature	-77.6**	-93.8***	-11.8	-19.2
	(33.8)	(32.4)	(44.4)	(39.7)
Constant	59,319***	59,879***	53,733***	53,232***
	(2,742)	(2,615)	(3,754)	(3,358)
Number of Observations	171	170	83	82
Adjusted R-Squared	0.551	0.475	0.694	0.564

^ Employee compensation (wages, salaries, and benefits) divided by the number of wage and salary workers adjusted for the cost of living.
^^ Percent of the workforce aged 25 to 64 with a bachelor's degree or higher.

Sources: U.S. Department of Commerce, Bureau of Economic Analysis (compensation per worker 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).

250,000 in 2000 and the smaller sample of 83 metros as in Table 1. 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 is less than 500,000. In the large 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.[12]

According to the results in Table 2, 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 four regressions. The estimated coefficients on the STEM variable range from a low of 1,396 to a high of 2,565. 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 coefficients estimated for the STEM share indicate that this difference in STEM intensity of employment makes average annual compensation per worker in Metro Austin $4,500 to $8,200 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 San Jose, especially in the smaller sample of 83 metro areas.

The regression analysis does not show educational attainment to be a highly significant determinant of earnings per worker. The estimated coefficients for educational attainment in the workforce are small in size and statistically significant in only one of the four 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 controlled for elsewhere 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.[13] 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

[12] 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.
[13] The correlation coefficient between bachelor's degree or more share in the workforce and STEM share of employment is around 0.78 in both samples.

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, we would expect January temperature to be negatively related to real per capita earnings. The coefficient on January temperature is negative in all four regressions but statistically significant only in regressions using the large sample of metro areas. In these two regressions, the climate coefficients range in size from 78 to 94. 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 $2,400 and $2,900 per year per worker.

Earnings Per Capita

Table 3 shows regression results when both the dependent variable and the human capital variables are expressed in per capita rather than per worker terms. Results for two samples are shown. The sample with 172 metro areas adds the Poughkeepsie-Middletown, NY metro area (recently designated). The smaller sample of 53 metro areas is limited to those with a population of at least 1 million in 2019. Earnings are again adjusted for the cost of living.

The most notable difference in results when comparing Tables 2 and 3 is that in the per capita analysis, both the STEM share and educational attainment are statistically significant. The emergence of the educational attainment of the population as a significant determinant of earnings per capita may have to do with the fact that these regressions do not include the employment-to-population ratio as an explanatory variable.

Regressions 3 and 4 in Table 3 are similar to regressions 1 and 2 except that the dependent variable is narrowed to include only the wages and salaries of workers in non-STEM occupations. The interesting and significant result of these regressions is that STEM intensity in a metro area is shown to have a positive effect on the real earnings of workers in non-STEM occupations.

Personal Income Per Capita

A variable frequently used to measure prosperity and economic performance in a metro 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. Table 4 shows the results of regression analyses of determinants of real per capita personal income in 2018. Explanatory variables include the variables used to explain earnings per worker (human capital variables and climate), the ratio of employment to population and, as an indicator of the importance of nonearnings income, the percent of the metro area population that is 65 years or older.

Regressions 1, 3, 4, and 5 are from Hill (2021). The most striking conclusion from these 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 three of the four regressions. The STEM variable, on the other hand, is significant only in the small sample which 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.

TABLE 3
REGRESSION ANALYSIS OF REAL EARNINGS PER CAPITA IN 2018

	Dependent Variable: Real Per Capita Wage and Salary Earnings		Dependent Variable: Real Per Capita Non-STEM Earnings	
Independent Variable	**Regression 1**	**Regression 2**	**Regression 3**	**Regression 4**
Educational Attainment, 2014 to 2018^	606.4***	556.3**	271.0***	158.5***
	(135.3)	(240.5)	(62.9)	(84.8)
STEM Employment as a Share of Total Population, 2019	2,553.0***	2,887.2***	633.4***	415.3**
	(397.9)	(579.1)	(185.0)	(204.2)
Mean January Temperature	-96.7***	-117.3**	-111.0***	-142.6***
	(29.0)	(46.9)	(13.5)	(16.5)
Constant	24,447***	26,971***	20,090***	24,684***
	(2,153)	(4,323)	(1,002)	(1,524)
Number of Observations	172	53	172	53
Adjusted R-Squared	0.693	0.748	0.646	0.733

^ Number aged 25 to 64 with a bachelor's degree or higher as a share of the total population.

Sources: U.S. Department of Commerce, Bureau of Economic Analysis (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).

TABLE 4
REGRESSION ANALYSIS OF REAL PER CAPITA PERSONAL INCOME IN 2018

	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^	703.1*** (104.2)		333.5*** (120.4)	403.2*** (123.6)	238.5* (139.6)	
College Educated as a Share of the Total Population, 2014 to 2018^^		1,276.5*** (189.3)				981.4*** (224.0)
STEM Share of Total Employment, 2019	-65.4 (338.7)		245.8 (316.2)	1,181.1*** (371.7)	510.5 (438.5)	
STEM Employment as a Share of Total Population, 2019		-212.7 (556.7)				1,282.8** (539.4)
Mean January Temperature	-64.5 (42.0)	-35.8 (40.6)	-34.6 (39.4)	-116.2** (44.9)	-82.8** (40.7)	-99.1** (43.7)
Share of Population 65 and Older, 2014 to 2018			661.7*** (141.2)		349.7* (208.1)	
Total Employment-to-Population Ratio, 2018			495.1*** (104.6)		459.2*** (99.5)	
Constant	34,163*** (3,060)	34,082*** (3,013)	2,606 (6,052)	39,247*** (3,517)	13,046* (6,789)	37,262*** (4,027)
Number of Observations	171	172	171	83	82	53
Adjusted R-Squared	0.408	0.448	0.510	0.615	0.654	0.725

^ Percent of the population aged 25 years and older with a bachelor's degree or higher.
^^ Number aged 25 to 64 with a bachelor's degree or higher as a share of the total population.

Sources: U.S. Department of Commerce, Bureau of Economic Analysis (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).

The coefficients on the variable measuring elderly share in the population are positive and statistically significant, especially in the large sample regression. The larger size of the coefficient in the large sample is due to a greater representation of retirement communities in that sample. The sample with 171 metro areas 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, depends not only on earnings per worker but also on the percent of the population that is employed. The employment-to-population variable included in regressions 3 and 5 was measured as the ratio of total employment (wage and salary workers plus number of proprietors) to the population. The estimated coefficients of the employment-to-population ratio are statistically significant at the 99 percent level of confidence, and they are large in size. Using the coefficient from regression 5, 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 the employment-to-population ratio is that the inclusion of this variable substantially reduces the estimated coefficient of the educational attainment variable. Much of the effect that educational attainment is found to have on per capita personal income 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.[14]

Regressions 2 and 6 do not include the employment-to-population ratio as an explanatory variable. The coefficients on educational attainment are highly significant and very large in size. So, it may be that the educational attainment variable is picking up some of the effect that education levels have on the percent of the population that is employed. The STEM employment variable, which is measured as a percent of the population rather than total employment, is significant only in the small sample which includes the San Jose metro area.

Understanding Differences in Growth and Prosperity Across 10 Selected Metro Areas

Population Growth

Table 5 uses results from regression 4 in Table 1 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 is the sum of deviations attributed to

[14] In alternative regressions of the employment-to-population ratio on college share and the other explanatory variables in the model, college share is significant in all cases at a 99% 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.

TABLE 5
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 4 in Table 1.

differences in January temperature, housing supply elasticity, college share from 2005 through 2007, and, to complete the accounting, the unexplained residual from regression 4.

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 period from 2000 to 2018. 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 5, 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 4 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.

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 83-metro-area average. 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 factors served to reduce Metro Tucson population growth by another 7 percentage points.

Earnings Per Worker

Table 6 uses results from regression 4 in Table 2 to account for 2018 compensation per worker in the 10 metro areas and their deviations from the 82-metro-area average (excluding San Jose).

TABLE 6
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 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 of real compensation per worker in 2018 was $69,791.

Source: Calculations made from regression 4 in Table 2.

Because of the particular regression used in the decompositions (e.g., the use of results from the 82-metro-area sample rather than the 170-metro-area sample), educational attainment is relatively important, and climate is relatively unimportant, as determinants of earnings deviations.

The STEM share of employment is the most important factor in determining whether compensation 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 is to a large extent a consequence of a lack of STEM jobs in the area.

Educational attainment is highly correlated with the STEM share. So, 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 Table 6 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. Compensation per worker in these metros is 5-to-8 percent above what can be explained by the regression. 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.

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 area. 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.[15]

Focusing on the two large metro areas in Arizona, real compensation per worker in Phoenix is fairly well explained by human capital and climate. The STEM share of employment in Phoenix is a little above the 82-metro-area average (5.9 versus 5.5 percent), while Phoenix's college share

[15] Empirical support for this explanation comes from the "STEM Employment and Earnings" chapter of this report. The quality of STEM workers in individual metro areas is 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.

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. Warm winters contribute a small amount to the shortfall of average earnings in Phoenix relative to the 82-metro-area average.

Real compensation per worker in Metro Tucson is not as well explained by human capital and climate. Similar to Phoenix, Tucson's moderately high STEM share of employment is offset by its moderately low level of college educational attainment, and warm winters exercise a small negative effect on earnings per worker. But real compensation per worker in Metro Tucson is 8 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 7 uses the results from regression 5 in Table 4 to explain differences in real per capita personal income between each of the 10 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:

- High levels of human capital in 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 representation 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. The selected metro areas in this analysis 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

TABLE 7
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 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 of real per capita personal income in 2018 was $54,345.

Source: Calculations made from regression 5 in Table 4.

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 7 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.

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 systematically narrowed. In U.S. states, income gaps closed at an average annual rate of 1.8 percent. Then beginning in the 1980s, regional convergence slowed. The rate of convergence of incomes between states 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 (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.

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.

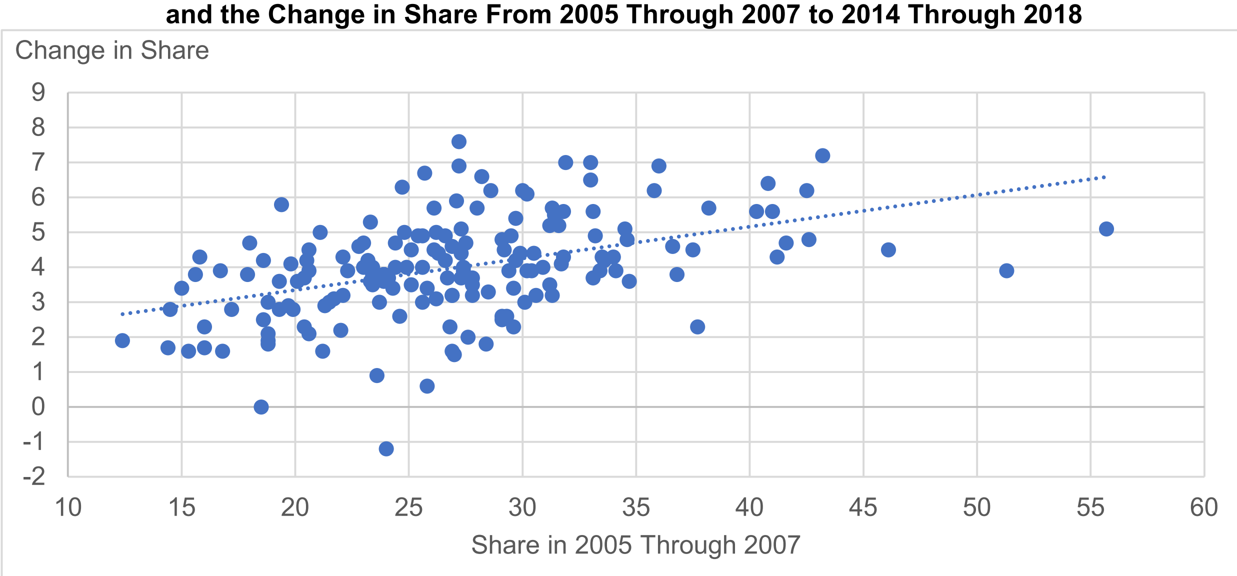
Berry and Glaeser (2005) used a highly specific model of urban agglomeration to explain the phenomenon of increasing urban concentration of skilled workers as the result of a growing tendency for innovation to be carried out by high-skilled entrepreneurs who start firms that hire other skilled people. 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 2 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 8 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 2. Among metro areas with the largest gains in college share are the large information technology and innovation hubs of San Jose, Boston, Seattle, and San Francisco. These metro areas had gains in college share that were not only large in absolute terms but that exceeded what would be expected on the basis of their initial college shares. Also among metros with large

CHART 2
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 8
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 2.

gains in college share are the Asheville, Denver, and Nashville metro areas — places with culture and natural amenities that have made them increasingly desirable places to live.

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 college share.

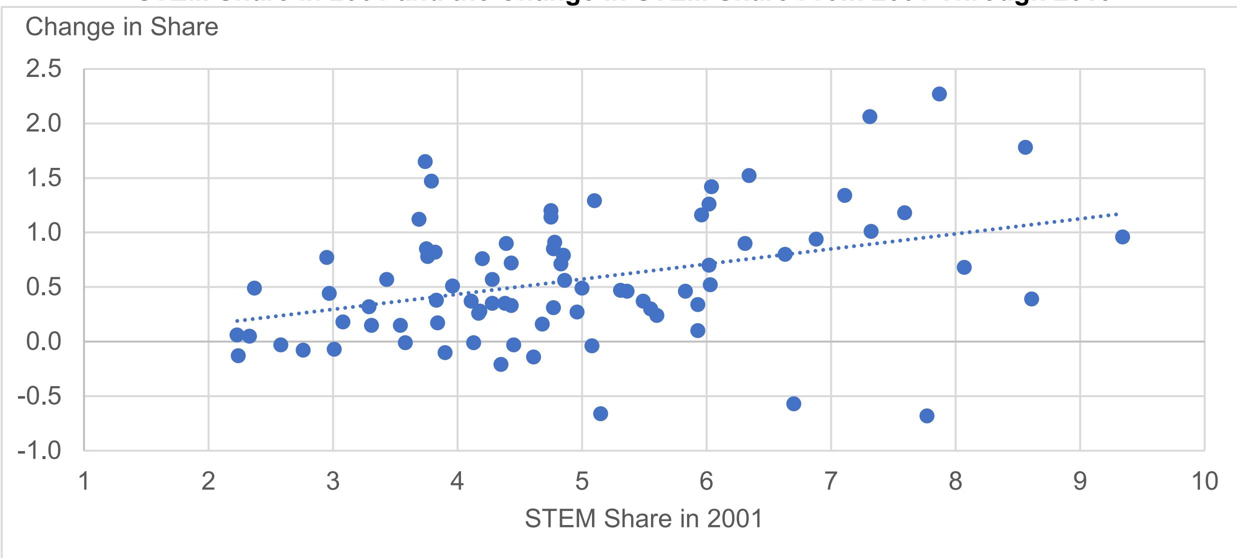
Chart 3 shows for a smaller sample of larger metro areas (where STEM activities seem to matter more for real per capita income) a positive correlation between the STEM share of employment in 2001 and the change in STEM share from 2001 to 2019.[16] The coefficient on the initial STEM share in a univariate regression is 0.138 with a standard error of 0.038. The adjusted R-squared is 0.14.

Table 9 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

[16] The sample analyzed consists of the 83 metro areas included in Table 1 less the San Jose and Wichita metro areas, which proved to be extreme outliers.

CHART 3
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: See the "STEM Employment and Earnings" chapter of this paper.

superstar information technology hubs of the San Francisco, San Jose, Seattle, and Boston metro areas but also some fast-climbing high-tech areas such as Raleigh and Salt Lake City. Also experiencing large gains in the STEM share were older, more traditional employers of STEM workers such as Metro Detroit and Metro Kansas City. Metro Phoenix experienced a gain in the STEM share of only 0.30 percentage points, which was 0.35 points below expectations. Metro Tucson had a gain in STEM share of 0.46 which was 0.23 percentage points below what would be expected on the basis of its initial STEM share.

Setting Aspirational Goals

The regression results suggest that those metro areas with relatively higher STEM intensity and educational attainment levels are likely to achieve higher levels of prosperity as measured by per capita personal income and per capita earnings. This section compares the Phoenix and Tucson metro areas to metro areas of comparable size and examines the likely effects from raising STEM intensity and educational attainment in the workforce in the Phoenix and Tucson areas.

The values for each of the dependent and independent variables used in the preceding section are displayed in Table 10 for the 53 metro areas with a population of at least 1 million in 2019. Ranks among the 53 metro areas are included for most of the variables. In addition, the average rank of the two human capital variables is presented, along with a prosperity rank that is based on the average rank of per capita personal income and per capita wage and salary earnings. The income and earnings measures have been adjusted to reflect the differential cost of living across the metro areas.

TABLE 9
PERCENTAGE-POINT CHANGE IN 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: U.S. Department of Commerce, Census Bureau, American Community Survey (educational attainment) and univariate regression presented in Chart 3.

Highly ranked metro areas based on human capital generally rank highly on prosperity. The top 25 metro areas based on human capital include 18 of the top 25 metro areas based on prosperity. Exceptions include the Atlanta, Portland, Raleigh, and San Diego areas, where prosperity lags levels that are predicted by the human capital measures. In the case of San Diego and to some degree the other three metro areas, the negative correlation between January temperature and earnings is no doubt a contributing factor and the allure of living in any of these four metro areas may have had a dampening impact on earnings growth versus population growth, eroding the per capita measures.

Metro Phoenix ranks 41st in the average human capital measure and 49th in prosperity, while Metro Tucson ranks 45th and 52nd respectively in these measures. The low ranks are in part attributable to Arizona's attractive climate as discussed below. Indeed, metro areas ranked from 41st to 53rd in the human capital ranking include 10 metro areas ranked 42nd or lower in the prosperity ranking. Most of these metro areas have temperate winter climates, suggesting that residents trade earnings for climate amenities. Among the 12 metro areas with the warmest January temperature, only Houston ranks above the median in prosperity, and only San Diego ranks above the median in human capital.

Table 11 depicts the top 10 metro areas as ranked by human capital. Aspirations for attaining top-10 ranks on human capital may be overly ambitious for Metro Phoenix and Metro Tucson. It would require an increase of more than 10 percentage points (a gain of 67 percent) in the share of

TABLE 10
53 LARGEST METROPOLITAN AREAS RANKED BY HUMAN CAPITAL: VARIABLE RANK AND VALUE

(Columns Are Explained at End of Table)

R1	R2		Education		STEM		T	PCPI		PC Earnings		Non-STEM	
1	1	San Jose-Sunnyvale-Santa Clara, CA	1	29.2%	1	11.42%	50.0	1	$82,081	1	$77,067	9	$26,252
2	2	San Francisco-Oakland-Berkeley, CA	2	28.7	3	5.93	50.0	2	75,550	2	56,140	19	24,708
6	3	Washington-Arlington-Alexandria, DC-VA-MD-WV	3	28.4	4	5.83	33.3	8	61,530	7	50,493	7	26,859
3	4	Boston-Cambridge-Newton, MA-NH	4	27.2	5	5.42	29.9	3	68,909	3	55,540	1	28,467
4	5	Seattle-Tacoma-Bellevue, WA	8	23.8	2	6.05	42.9	4	66,094	5	51,465	10	26,125
29	6	Raleigh-Cary, NC	5	25.5	8	4.84	40.6	24	56,982	31	41,377	39	22,032
14	7	Austin-Round Rock-Georgetown, TX	7	23.8	7	4.88	51.4	20	58,656	12	46,724	34	22,621
8	8	Denver-Aurora-Lakewood, CO	6	24.1	9	4.78	30.8	11	61,284	8	48,446	8	26,416
10	9	Minneapolis-St. Paul-Bloomington, MN-WI	10	22.5	11	4.24	15.9	10	58,484	26	43,453	4	27,734
23	9	Baltimore-Columbia-Towson, MD	11	23.1	10	4.26	33.3	21	61,296	10	47,341	24	24,232
33	11	Portland-Vancouver-Hillsboro, OR-WA	12	21.8	14	4.08	41.4	32	54,905	32	41,319	22	24,438
5	12	Hartford-East Hartford-Middletown, CT	13	21.7	15	3.79	20.7	5	63,014	6	50,593	3	27,819
39	13	San Diego-Chula Vista-Carlsbad, CA	18	20.7	12	4.15	57.9	40	52,737	40	38,525	42	21,549
34	14	Atlanta-Sandy Springs-Alpharetta, GA	16	20.8	19	3.28	44.0	37	53,929	28	42,732	40	21,995
24	15	Columbus, OH	20	20.3	16	3.53	29.3	26	55,674	22	44,162	13	25,366
21	16	Kansas City, MO-KS	21	20.0	17	3.47	28.8	22	57,899	20	44,728	18	24,800
8	17	Pittsburgh, PA	19	20.5	21	3.17	28.3	6	62,376	13	46,464	17	24,845
26	17	Salt Lake City, UT	34	17.3	6	4.98	30.4	41	52,417	9	48,178	2	28,035
18	19	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	15	21.0	26	3.00	32.7	12	61,138	25	43,565	28	23,189
20	19	Richmond, VA	17	20.7	24	3.00	37.1	17	59,627	17	44,355	16	25,161
12	21	Milwaukee-Waukesha, WI	22	19.6	20	3.19	22.7	15	60,132	15	45,553	5	27,421
22	22	Dallas-Fort Worth-Arlington, TX	29	18.3	18	3.36	47.2	29	55,498	29	45,519	33	22,829
28	23	Charlotte-Concord-Gastonia, NC-SC	25	19.1	23	3.06	40.8	30	55,389	30	44,109	29	23,014
31	23	Detroit-Warren-Dearborn, MI	35	17.3	13	4.11	25.3	27	55,588	27	41,317	41	21,988
11	25	New York-Newark-Jersey City, NY-NJ-PA	9	18.8	40	2.56	32.5	7	59,148	19	47,341	27	23,599
12	25	Indianapolis-Carmel-Anderson, IN	27	23.7	22	3.14	28.5	19	61,790	7	46,427	14	25,279
16	27	Chicago-Naperville-Elgin, IL-IN-WI	14	21.4	36	2.65	25.1	18	59,195	18	45,032	23	24,338

(continued)

TABLE 10 (continued)
53 LARGEST METROPOLITAN AREAS RANKED BY HUMAN CAPITAL: VARIABLE RANK AND VALUE

(Columns Are Explained at End of Table)

R1	R2		Education		STEM		T	PCPI		PC Earnings		Non-STEM	
16	28	St. Louis, MO-IL	24	19.2%	27	2.99%	31.7	9	$61,410	27	$43,305	15	$25,212
43	29	Rochester, NY	28	18.6	25	3.00	21.9	42	52,371	42	37,409	32	22,937
36	30	Los Angeles-Long Beach-Anaheim, CA	26	18.9	34	2.68	56.5	35	54,580	36	40,065	38	22,314
18	31	Cincinnati, OH-KY-IN	31	18.0	30	2.96	30.3	14	60,195	23	44,126	21	24,611
7	32	Nashville-Davidson--Murfreesboro--Franklin, TN	23	19.6	39	2.60	38.4	13	61,068	4	51,886	11	25,956
37	33	Sacramento-Roseville-Folsom, CA	37	17.2	28	2.98	46.7	36	54,323	39	38,986	37	22,392
15	34	Cleveland-Elyria, OH	36	17.3	32	2.91	28.5	16	59,642	19	44,746	6	26,990
24	35	Houston-The Woodlands-Sugar Land, TX	40	17.1	31	2.94	54.2	31	55,086	17	45,339	46	20,819
44	36	Virginia Beach-Norfolk-Newport News, VA-NC	43	16.5	29	2.96	41.3	43	52,185	44	36,286	36	22,424
35	37	Grand Rapids-Kentwood, MI	38	17.1	35	2.68	24.5	33	54,732	34	41,276	12	25,580
39	38	Buffalo-Cheektowaga, NY	30	18.2	44	2.32	25.0	39	53,180	41	38,311	25	23,824
39	39	Providence-Warwick, RI-MA	32	17.6	43	2.34	29.2	34	54,640	46	35,231	30	23,014
27	40	Birmingham-Hoover, AL	33	17.4	46	2.20	44.1	23	57,473	29	42,184	26	23,613
49	**41**	**Phoenix-Mesa-Chandler, AZ**	**48**	**15.4**	**33**	**2.82**	56.0	**50**	**47,018**	**48**	**34,602**	**48**	**20,641**
50	42	Orlando-Kissimmee-Sanford, FL	41	16.8	42	2.42	60.2	52	44,064	47	35,070	47	20,719
38	43	Oklahoma City, OK	47	15.7	37	2.65	37.7	38	53,552	38	39,187	35	22,499
30	44	Louisville/Jefferson County, KY-IN	44	16.4	41	2.55	34.5	28	55,544	30	41,972	20	24,698
52	**45**	**Tucson, AZ**	**50**	**14.4**	**38**	**2.62**	53.5	**51**	**46,888**	**52**	**28,729**	**52**	**17,544**
47	46	Miami-Fort Lauderdale-Pompano Beach, FL	39	17.1	51	1.66	67.9	45	52,073	50	32,707	51	18,007
31	47	New Orleans-Metairie, LA	42	16.7	49	1.75	53.1	25	55,719	35	40,223	44	21,083
51	47	Tampa-St. Petersburg-Clearwater, FL	46	15.8	45	2.28	61.3	49	47,717	51	31,876	50	18,746
44	49	Jacksonville, FL	45	16.0	48	2.08	53.4	44	52,098	43	36,689	45	20,867
46	50	San Antonio-New Braunfels, TX	51	14.1	47	2.10	51.5	47	50,048	45	36,284	49	20,196
42	51	Memphis, TN-MS-AR	49	15.0	50	1.70	41.2	46	51,685	37	40,053	31	22,963
48	52	Las Vegas-Henderson-Paradise, NV	52	12.2	52	1.44	48.8	48	48,647	49	33,793	43	21,234
53	53	Riverside-San Bernardino-Ontario, CA	53	10.3	53	0.97	56.5	53	37,838	53	22,991	53	16,165

(continued)

TABLE 10 (continued)
53 LARGEST METROPOLITAN AREAS RANKED BY HUMAN CAPITAL: VARIABLE VALUES AND RANK

Column Descriptions:
R1: Prosperity rank; the average rank of per capita personal income and per capita wages and salaries.
R2: Human capital rank; the average rank of the percentage of the labor force age 25 to 64 with at least a bachelor’s degree and per capita STEM employment.
Education: Number aged 25 to 64 with a bachelor’s degree or higher as a share of the entire population, 2014 through 2018.
STEM: STEM employment as a share of total population, 2019.
T: Mean January temperature in Fahrenheit degrees.
PCPI: Per capita personal income adjusted for the cost of living, 2018.
PC Earnings: Per capita wage and salary earnings adjusted for the cost of living, 2018.
Non-STEM: Per capita non-STEM earnings adjusted for the cost of living, 2018.

Sources: U.S. Department of Commerce, Bureau of Economic Analysis (personal income, earnings, 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).

TABLE 11
TOP-10 METROPOLITAN AREAS BASED ON HUMAN CAPITAL: VARIABLE VALUES AND RANKS AMONG 53 LARGEST METROPOLITAN AREAS

(Columns Are Explained at End of Table 10)

R1	R2		Education		STEM		T	PCPI		PC Earnings		Non-STEM	
1	1	San Jose-Sunnyvale-Santa Clara, CA	1	29.2%	1	11.42%	50.0	1	$82,081	1	$77,067	9	$26,252
2	2	San Francisco-Oakland-Berkeley, CA	2	28.7	3	5.93	50.0	2	75,550	2	56,140	19	24,708
6	3	Washington-Arlington-Alexandria, DC-VA-MD-WV	3	28.4	4	5.83	33.3	8	61,530	7	50,493	7	26,859
3	4	Boston-Cambridge-Newton, MA-NH	4	27.2	5	5.42	29.9	3	68,909	3	55,540	1	28,467
4	5	Seattle-Tacoma-Bellevue, WA	8	23.8	2	6.05	42.9	4	66,094	5	51,465	10	26,125
29	6	Raleigh-Cary, NC	5	25.5	8	4.84	40.6	24	56,982	31	41,377	39	22,032
14	7	Austin-Round Rock-Georgetown, TX	7	23.8	7	4.88	51.4	20	58,656	12	46,724	34	22,621
8	8	Denver-Aurora-Lakewood, CO	6	24.1	9	4.78	30.8	11	61,284	8	48,446	8	26,416
10	9	Minneapolis-St. Paul-Bloomington, MN-WI	10	23.1	11	4.24	15.9	10	61,296	10	47,341	4	27,734
23	9	Baltimore-Columbia-Towson, MD	11	22.5	10	4.26	33.3	21	58,484	26	43,453	24	24,232
10	5	Average of the Top 10	6	25.6	6	5.77	37.8	10	65,087	11	51,805	16	25,545
49	41	Phoenix-Mesa-Chandler, AZ	48	15.4	33	2.82	56.0	50	47,018	48	34,602	48	20,641
52	45	Tucson, AZ	50	14.4	38	2.62	53.5	51	46,888	52	28,729	52	17,544
-39	-36	Phoenix Difference From the Average	-42	-10.3	-27	-2.95	18.2	-40	-18,069	-38	-17,203	-33	-4,904
-42	-40	Tucson Difference From the Average	-44	-11.2	-32	-3.14	15.7	-41	-18,199	-42	-23,076	-37	-8,001
-35	-34	Phoenix Difference From Austin	-41	-8.5	-26	-2.06	4.6	-30	-11,638	-36	-12,122	-14	-1,980
-38	-38	Tucson Difference From Austin	-43	-9.4	-31	-2.25	2.1	-31	-11,768	-40	-17,995	-18	-5,077

Sources: U.S. Department of Commerce, Bureau of Economic Analysis (personal income, earnings, 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).

the workforce aged 25 to 64 with at least a bachelor's degree for Metro Phoenix to match the average of the top 10. The necessary increase is even larger for Metro Tucson. In STEM employment per capita, Metro Phoenix needs an increase of nearly 3 percentage points (more than a 100 percent increase). A somewhat larger gain is necessary in Metro Tucson.

Reaching the top 10 would result in a significant improvement in the prosperity measures in the Phoenix and Tucson areas. The top-10 average for per capita personal income is more than $18,000 higher than in either the Phoenix or Tucson areas with, at most, only about $4,000 likely explained by climate.[17] Similarly, average top-10 wage and salary earnings per capita is more than $17,000 higher than in Metro Phoenix and $23,000 higher than in Metro Tucson. The average top-10 non-STEM earnings per capita is $5,000 higher than in Metro Phoenix and $8,000 higher than in Metro Tucson, with at most $3,000 explained by climate.

Among the top 10, Metro Austin is located at a comparable latitude, and is closest in mean January temperature, to the Phoenix and Tucson areas. Attaining human capital rankings comparable to Metro Austin would require nearly an 8.5 percentage-point (55 percent) increase in Metro Phoenix. STEM intensity would need to rise more than 2 percentage points (73 percent). The improvements would need to be larger in Metro Tucson.

Personal income per capita, wage and salary earnings per capita, and non-STEM earnings per capita in Metro Austin exceed the figures in Metro Phoenix by $11,638, $12,122 and $1,980 respectively and exceed the figures in Metro Tucson by $11,768, $17,995 and $5,077 respectively. This indicates that raising the human capital measures in the Arizona metro areas to levels matching Metro Austin would yield substantial benefits and that climate alone does not explain the prosperity shortfalls observed in Arizona's metro areas since Metro Austin's climate amenities are comparable.

The data in Table 12 depict the benefits that might accrue should Arizona's metro areas set a more modest goal of matching the average of the 11th-through-20th-ranked metro areas on the human capital measures. Metro Austin is replaced by Metro San Diego as an area at a comparable latitude with a similar mean January temperature.

To match the average of the second-10 metro areas on the educational attainment variable, a 5.1 percentage-point (33 percent) increase is needed in Metro Phoenix and a 6.1 percentage-point (42 percent) increase is needed in Metro Tucson. Increases in STEM workers per capita would need to be 0.83 percentage points (a 29 percent increase) in Metro Phoenix and 1.02 percentage points (a gain of 39 percent) in Metro Tucson respectively to move the metro areas to the average of the second 10.

The potential rewards in terms of prosperity remain significant. The second-10 average for personal income per capita is more than $10,000 higher than in either Metro Phoenix or Metro Tucson with, at most, only about $4,000 likely explained by climate.[18] Similarly, average wage

[17] Univariate regressions of the income and earnings measures were used to estimate the role played by climate. Smaller estimates were obtained from the multiple regression results.
[18] Univariate regressions of the income and earnings measures were used to estimate the role played by climate. Smaller estimates of the climate effect were obtained from the multiple regression results.

TABLE 12
SECOND-10 METROPOLITAN AREAS BASED ON HUMAN CAPITAL: VARIABLE VALUES AND RANKS AMONG 53 LARGEST METROPOLITAN AREAS

(Columns Are Explained at End of Table 10)

R1	R2		Education		STEM		T	PCPI		PC Earnings		Non-STEM	
33	11	Portland-Vancouver-Hillsboro, OR-WA	12	21.8%	14	4.08%	41.4	32	$54,905	32	$41,319	22	$24,438
5	12	Hartford-East Hartford-Middletown, CT	13	21.7	15	3.79	20.7	5	63,014	6	50,593	3	27,819
39	13	San Diego-Chula Vista-Carlsbad, CA	18	20.7	12	4.15	57.9	40	52,737	40	38,525	42	21,549
34	14	Atlanta-Sandy Springs-Alpharetta, GA	16	20.8	19	3.28	44.0	37	53,929	28	42,732	40	21,995
24	15	Columbus, OH	20	20.3	16	3.53	29.3	26	55,674	22	44,162	13	25,366
21	16	Kansas City, MO-KS	21	20.0	17	3.47	28.8	22	57,899	20	44,728	18	24,800
8	17	Pittsburgh, PA	19	20.5	21	3.17	28.3	6	62,376	13	46,464	17	24,845
26	17	Salt Lake City, UT	34	17.3	6	4.98	30.4	41	52,417	9	48,178	2	28,035
18	19	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	15	21.0	26	3.00	32.7	12	61,138	25	43,565	28	23,189
20	19	Richmond, VA	17	20.7	24	3.00	37.1	17	59,627	21	44,355	16	25,161
23	15		19	20.5	17	3.65	35.1	24	57,372	22	44,462	20	24,720
49	41	Phoenix-Mesa-Chandler, AZ	48	15.4	33	2.82	56.0	50	47,018	48	34,602	48	20,641
52	45	Tucson, AZ	50	14.4	38	2.62	53.5	51	46,888	52	28,729	52	17,544
-26	-26	Phoenix Difference From the Average	-30	-5.1	-16	-0.83	20.9	-26	-10,354	-26	-9,860	-28	-4,079
-29	-30	Tucson Difference From the Average	-32	-6.1	-21	-1.02	18.4	-27	-10,484	-30	-15,733	-32	-7,176
-10	-28	Phoenix Difference From San Diego	-30	-5.3	-21	-1.33	-1.9	-10	-5,719	-8	-3,923	-6	-908
-13	-32	Tucson Difference From San Diego	-32	-6.3	-26	-1.52	-4.4	-11	-5,849	-12	-9,796	-10	-4,005

Sources: U.S. Department of Commerce, Bureau of Economic Analysis (personal income, earnings, 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 salary earnings per capita is nearly $10,000 higher than in Metro Phoenix and nearly $16,000 higher than in Metro Tucson. The second-10 average of non-STEM earnings per capita is $4,100 higher than in Metro Phoenix and $7,200 more than in Metro Tucson.[19]

Attaining educational attainment comparable to in Metro San Diego would require slightly greater increases in the Phoenix and Tucson areas than those needed to match the second-10 average. STEM workforce intensity per capita would rise 1.3 and 1.5 points respectively in each metro. To match Metro San Diego in STEM intensity would require a greater improvement than compared to the second-10 average. The benefits in income and earnings would not be as large as in the comparison to the second-10 average, but this likely is not a meaningful comparison since income and earnings in Metro San Diego likely are held down by proximity to the ocean and by the favorable year-round climate.

[19] Climate explains at most about $3,000 of this non-STEM earnings differential in Metro Phoenix.

STEM EMPLOYMENT AND EARNINGS

Economic activities closely associated with STEM — science, technology, engineering, and mathematics — are the focus of this chapter. STEM essentially is synonymous with "high technology." The latest STEM data and the change over time are analyzed in this paper.

Conceptually, it is far superior to define STEM by occupation than by industry. Every worker classified into a STEM occupation, such as electronics engineers, is involved in STEM activities. In contrast, though a particular industry, such as semiconductor manufacturing, may be STEM intensive, a sizable proportion of its workforce do not work in STEM occupations, such as business support functions and production activities that may not require a substantive STEM education or knowledge base. On the other hand, industries that have little relationship to STEM, such as retail trade, have some employees working in STEM occupations, particularly those related to computers. While occupational data are emphasized in this report, industrial data also are analyzed since so many prior studies have used industrial data.

Introduction

Employment and Earnings Data

The data used to analyze STEM occupations and STEM-intensive industries were obtained from Emsi (www.economicmodeling.com), a private-sector company providing selected economic and related data for the nation, states, metropolitan areas, and counties. Access to the data is available only to subscribers, and limits are in place as to the amount of detail a subscriber can make public. Thus, data for specific occupations are not revealed in this paper.

Emsi updates its data estimates quarterly; the data used in this report come from Emsi's third quarter 2020 data release. Emsi uses a variety of sources, predominantly federal government agencies, to develop its industrial and occupational estimates. The advantage of using Emsi's data is that Emsi imputes values for the large volume of data that are withheld by the federal government. Federal laws intended to prevent the disclosure of information of a specific business or a specific individual result in a substantial amount of data being withheld from publication except for highly populous geographic areas.

Among the data available from Emsi are employment and average earnings per job by industry and employment and median earnings per job by occupation. The industrial data and the occupational employment estimates are available annually for 2001 through 2019, but the earliest occupational earnings estimates are for 2005. The overall U.S. median earnings per job from the occupational data of $48,522 in 2019 is substantially lower than the average earnings per job from the industrial data of $69,072. A small number of individuals with extremely high earnings causes the average to be higher than the median.

Employment and median/average earnings are reported by Emsi for each of four categories of workers; totals are available for any combination of two or more categories. The first category corresponds to the employment counted in the Quarterly Census of Employment and Wages (QCEW), produced by the U.S. Department of Labor's Bureau of Labor Statistics (BLS). The QCEW counts wage and salary employees who are covered by the unemployment insurance program. Each quarter, employers report actual wages paid and the number of employees. The

QCEW data — subject to the disclosure restrictions — are reported quarterly by industry with a lag of five months.

Limitations of the QCEW data include no indication of the part-time/full-time status of employees, incomplete coverage of wage and salary employees, no coverage of the self-employed, and the withholding of much of the data. Emsi provides estimates of QCEW data that are withheld from publication due to the federal disclosure laws. Except for the most-populous metropolitan areas and states, employment and/or earnings are not disclosed for a substantial number of industries. Emsi's figure for the number of workers counted by the QCEW nationally in 2019 is 148.1 million.

Emsi's second category of workers consists of wage and salary workers who are not covered by unemployment insurance; the number was estimated by Emsi to be 6.8 million nationally in 2019. Those in the military and those working for railroads are included in this category, as are some employees of the federal government, religious organizations, etc.

The third category of workers consists of self-employed individuals whose self-employment constitutes a high proportion of their total earnings and working hours. Nationally in 2019, the number of self-employed was estimated by Emsi to be 10.8 million. Emsi's fourth category consists of those individuals with earnings from self-employment, but whose self-employment does not make up the majority of their earnings or time spent at work. Most of the 37.7 million individuals in this category likely are wage and salary workers as well. To avoid double counting, Emsi's fourth category is not included in the analyses in this report. National employment in the first three categories totaled 165.7 million in 2019. Emsi's industrial and occupational employment totals are identical.

The primary source for the occupational data reported by Emsi is the Occupational Employment Statistics (OES) program of the BLS, which releases estimates annually. Data for May 2019 were released in March 2020. The OES data are subject to serious limitations. Since the data are derived from a survey of employers, sampling error is a concern. Further, the survey instructs employers to report the number of employees in each occupation by wage range rather than report actual wages. In addition, the survey is conducted over a three-year cycle — it takes three years of semiannual surveying for the full panel of respondents to be surveyed. Thus, most of the responses used to produce the May 2019 estimates were collected before 2019, though the wage data from the earlier periods were adjusted for inflation. Emsi must estimate employment and earnings for workers not covered by the OES survey and for the substantial number of OES occupations for which employment and/or earnings data are withheld from publication.

The 2018 version of the Standard Occupational Classification (SOC) identifies 867 detailed occupations, each of which is assigned a six-digit number, such as 15-2041 (statisticians). The occupations are organized into 23 major groups. While Emsi's occupational data are based on the SOC, Emsi does not provide estimates for every SOC detailed occupation, combining some SOC occupations. Emsi releases estimates for 756 detailed occupations.

The 2017 version of the North American Industrial Classification System (NAICS) identifies 1,057 industries for the United States. Each industry is assigned a six-digit number, such as

334111 (electronic computer manufacturing). The industries are organized hierarchically into industry groups, subsectors, and 20 sectors. As in the occupational data, Emsi combines some of the detailed categories, providing estimates for 993 industries.

As in some federal government programs, such as the QCEW, Emsi does not allocate all economic activity to a specific county. Each state has a "county not reported" category.

Measurement of STEM Activity

Commonly, economic analyses focus on employment due to its simple concept and more ready availability. However, employment as reported in the United States has a serious shortcoming in that no measure of full-time equivalency is available: a part-time worker is counted the same as a full-time worker. In addition, earnings per job vary widely by occupation and industry; an indicator measured in dollars is more indicative of the impact of particular economic activities.

Aggregate earnings are estimated by multiplying employment by average/median earnings per job for each industry/occupation. STEM totals are obtained by summing employment/aggregate earnings across the relevant industries/occupations. While conceptually preferable to employment, the occupational aggregate earnings data are disadvantaged by the necessity of using median rather than average earnings per worker. Arithmetic operations using median values are limited. For example, using the median, the nonmetro portion of a state's aggregate earnings cannot be calculated as the state total minus the sum of the metro counties minus "county not reported." Thus, in this paper, both employment and aggregate earnings are used to measure STEM activities.

Two ways of measuring STEM activity are employed in this paper: (1) the total number of STEM workers and/or the total value of STEM aggregate earnings; and (2) STEM activity as a share of total employment and/or total aggregate earnings. The latter measure is emphasized.

Conceptually, overall earnings per job can be split into two components: (1) the occupational/industrial mix among STEM occupations/industries, and (2) other factors that cause earnings per job to vary across states and metro areas. The cost of living is one of these other factors.

To illustrate the importance of the occupational mix, consider the example of two metro areas with identical earnings per job in each STEM occupation. The overall aggregate earnings share will be lower in the metro area with a higher proportion of jobs in occupations with lower earnings, such as technicians.

In order to measure variations in the STEM occupational/industrial mix across geographic areas, a measure of job quality within the STEM occupations/industries — defined in terms of median/average earnings per job — was created by summing the following across the 81 STEM occupations/57 STEM industries:

> **(the difference in employment share from the national average) times (national median/average earnings as a ratio to the overall STEM median/average earnings less 1) times 100**

The employment share is measured as the percentage of total STEM employment in each STEM occupation/industry. The job quality measure by state and metro area is expressed relative to the national average. For example, a job quality value of 4.7 indicates that the STEM earnings per job figure is 4.7 percent higher than it would have been had the employment mix equaled the national average.

Adjustment for Inflation and the Cost of Living

When the total value of STEM aggregate earnings is used, the values are adjusted for the cost of living, which varies widely across the nation's states and metropolitan areas. The cost-of-living adjustment uses the regional price parity (RPP) estimates produced by the U.S. Department of Commerce's Bureau of Economic Analysis (BEA). Estimates of the RPP are available by state and metropolitan area.

The RPP series is available only for 2008 through 2019. The relative cost of living changes only slowly over time, with the most significant changes occurring at turning points in the economic cycle. In the analysis in this chapter, the 2008 RPP estimates were applied to the 2001 and 2005 earnings data. While this introduces some error, it is more accurate to compare metro areas based on imperfect cost-of-living estimates than to entirely ignore the large differences in the regional cost of living.

In order to compare the aggregate earnings figures for 2005 and 2019, inflation must be considered. The earnings data for 2005 were adjusted to 2019 dollars using the national gross domestic product implicit price deflator produced by the BEA.

Identification of STEM Occupations and Industries

Numerous efforts to identify STEM (or "high-technology") occupations and industries have been made (see the references for some of these sources). While the efforts have produced slightly different lists of occupations, the correspondence is strong across the sources. Based on the consensus of these efforts, the STEM occupational definition used in this report includes the following occupations:

- Three occupations in the "management" major group.
- All occupations in the "computer and mathematical" major group.
- The engineering portion of the "architecture and engineering" major group.
- The life and physical sciences portion of the "life, physical, and social science" major group.

A total of 81 STEM occupations have been selected. They have been grouped into six categories: computer, mathematical science (math), engineering, engineering technician, life and physical science (science), and science technician. See Appendix A for a list of the STEM occupations by category.

A significant difference in size, as measured by employment or aggregate earnings, existed across the six occupational categories in 2019, with the computer category the largest by far, followed by engineering. The other four categories were considerably smaller than engineering.

Much lesser consensus exists across the efforts to identify STEM-intensive industrial activities (see the references for these sources). In addition, most definitions of STEM-intensive industrial activities have been made at the industry group level (four-digit NAICS) rather than at the six-digit industry level. Thus, the authors of this report had to decide both which industry groups to classify as STEM intensive and which of the six-digit industries within the selected industry groups to include.

A total of 57 STEM-intensive industries have been selected, of which 47 are included in most lists. Even with the addition of 10 more industries, the STEM share of total U.S. employment in 2019 based on industries is less than the STEM share based on occupations. The STEM-intensive industries are listed in Appendix B.

Geographic Areas

A metropolitan area is defined by the federal government as one or more adjacent counties or county equivalents that have at least one urban core area of at least 50,000 population plus adjacent territory that has a high degree of social and economic integration with the core as measured by commuting ties. Currently, 384 metro areas (excluding Puerto Rico) consisting of 1,080 counties/county equivalents are defined. The federal government also defines 543 micropolitan areas consisting of 661 counties/county equivalents using the same criteria except that the core area has a population between 10,000 and 49,999. For this paper, the micropolitan areas are combined with the 1,401 counties not identified as being part of a metro or micro area to form the U.S. "nonmetropolitan area."

Economic activity is closely tied to individual labor market areas, which correspond to official definitions of metropolitan and micropolitan areas. The 384 metropolitan areas vary widely in size, with employment in 2019 ranging from 28,500 in the smallest metro area to 10.2 million in the largest. Half of the metro areas had employment of less than 125,000 in 2019.

Assuming that adequate data are available, metropolitan areas are the preferred level of geography for most economic analyses. However, most economic analyses are conducted at the state level, due to some combination of superior data, acknowledgement of state-level economic programs and organizations (such as the Arizona Commerce Authority), or ease of analysis. The analysis of data and reporting of results for 51 "states" (including the District of Columbia) is more manageable than for the nation's 384 metro areas.

Prior research revealed that even after adjusting for the cost of living, various economic measures are positively correlated with metro size, as measured by population or employment.[20] Similarly, the STEM shares of total aggregate earnings and of total employment are correlated with metro size, as measured by employment and aggregate earnings.

Due to the relationship between metro area size and STEM intensity, instead of comparing each metro area to the average of the 384 metro areas, each metro area is compared to a size-class average. Any number of size classes could be devised. For this analysis of STEM economic

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[20] For example, see the May 2017 Office of the University Economist papers "The Geographic Distribution of Average Earnings Per Worker" and "Job Quality in the Metropolitan Areas of the United States," available from https://economist.asu.edu/P3/job-quality.

activity, the nation's 384 metropolitan areas are grouped into six size classes by the number of workers in 2019. The selection of the size classes was based on a combination of natural breaks in the distribution of 2019 STEM activity as measured by STEM employment and aggregate earnings as a share of the total, and natural breaks in the distribution of 2019 employment, across the metro areas:

- 36 metro areas with employment of at least 1 million, accounting for 9.4 percent of the number of metro areas and 58.9 percent of metro area employment. In this paper, this group is referred to as either "the largest size class" or "SC1" (with "SC" the abbreviation for "size class").
- 45 metro areas with employment of between 350,000 and 999,999, accounting for 11.7 percent of metro areas and 16.4 percent of metro area employment. This is "SC2."
- 46 metro areas with employment of between 200,000 and 349,999, accounting for 12.0 percent of metro areas and 8.4 percent of metro area employment. This is "SC3."
- 62 metro areas with employment of between 125,000 and 199,999, accounting for 16.1 percent of metro areas and 6.8 percent of metro area employment. This is "SC4."
- 71 metro areas with employment of between 75,000 and 124,999, accounting for 18.5 percent of metro areas and 4.7 percent of metro area employment. This is "SC5."
- 124 metro areas with employment of less than 75,000, accounting for 32.3 percent of metro areas and 4.7 percent of metro area employment. This is "SC6" or "the smallest size class."

Based on employment, the STEM share in 2005 and 2019 was calculated for nonmetropolitan areas. The nonmetropolitan area of each state was calculated as the state total minus the sum of the metropolitan counties in the state minus the "county not reported" category. Direct measurement of the nonmetro area of each state is impractical due to the large number (more than 2,000) of nonmetro counties/county equivalents in the United States.

In this paper, the STEM analysis is performed first for the nation, second by state, and third by metropolitan area, with a particular focus on Arizona and its seven metro areas: Flagstaff (Coconino County), Lake Havasu City-Kingman (Mohave County), Phoenix-Mesa-Chandler (Maricopa and Pinal counties), Prescott Valley-Prescott (Yavapai County), Sierra Vista-Douglas (Cochise County), Tucson (Pima County), and Yuma (Yuma County). Each of Arizona's metro areas is compared to the figures for its size class.

Arizona's nonmetro area was calculated as the sum of its seven nonmetro counties: Apache, Gila, Graham, Greenlee, La Paz, Navajo, and Santa Cruz. It is compared to the national nonmetro area.

STEM Economic Activity in the United States

Table 13 provides an employment and aggregate earnings summary for the United States for 2019 and for the change over time based on both the occupational and industrial datasets.

STEM Occupations

2019. The 81 STEM occupations accounted for 10.7 percent of Emsi's 756 detailed occupations, but for only 5.51 percent of the U.S. workforce in 2019. However, the STEM share of total aggregate earnings was higher at 10.18 percent.

The 81 occupations are grouped into six STEM occupational categories. Nationally in 2019, the 13 computer occupations accounted for 56 percent of the STEM employment and 58 percent of the STEM aggregate earnings. The 19 occupations of the engineering category accounted for 22 percent of the STEM employment and 25 percent of the STEM aggregate earnings. The math category consists of only five occupations; there are 13 engineering technician occupations, 22 science occupations, and nine science technician occupations. These four categories combined were responsible for 22 percent of STEM employment and only 17 percent of STEM aggregate earnings.

The data by occupational category are provided in Table 13. The six largest STEM occupations in 2019 were in the computer category. The "software developers and software quality assurance analysts and testers" occupation alone accounted for 0.89 percent of total employment and 1.96 percent of total aggregate earnings, each more than twice the share of the second-ranked occupation.

Taken as a whole, the 81 STEM occupations nationally in 2019 had median earnings of $89,697 — 84.9 percent higher than the overall figure of $48,522. Compared to the median of non-STEM workers ($46,122), the median of STEM earnings was 94.5 percent higher.

Median earnings in 2019 were fairly similar in four of the STEM categories (see Table 14). Relative to the overall STEM median, the median for the engineering category was 12 percent higher, followed by the computer (+4 percent), math (+1 percent), and science (-3 percent) categories. In contrast, the median earnings figure was much lower than the overall STEM median in the science technician category (-46 percent) and in the engineering technician category (-36 percent).

Even within individual STEM categories, median earnings varied widely by occupation. "Computer and information systems managers" and "architectural and engineering managers" each earned more than three times the non-STEM figure, and "natural sciences managers" and "petroleum engineers" each earned at least 2.75 times more than the non-STEM median. In contrast, a few of the STEM technician occupations earned less than the non-STEM figure and most of the other STEM technician occupations had an earnings premium of less than 25 percent relative to the non-STEM median.

Change Over Time. With occupational earnings data not available prior to 2005, the 2005-to-2019 period is the focus for the change in employment and aggregate earnings. STEM's share of the total rose during this period, from 4.68-to-5.51 percent of employment (an 18 percent rise in 14 years) and from 8.48-to-10.18 percent of aggregate earnings (a 20 percent increase).

Based on annual data, the STEM share of occupational employment fell slightly during the early 2000s, but increased in 2005 and in each succeeding year. The STEM share of occupational aggregate earnings rose in each year after 2005. The computer category was responsible for nearly all of the increase in the overall STEM share. Small increases in the math, engineering, and science categories were nearly offset by declines in the two technician categories

TABLE 13
STEM EMPLOYMENT AND AGGREGATE EARNINGS IN THE UNITED STATES

	Employment	Aggregate Earnings in Millions*	STEM Share of Total: Employment	STEM Share of Total: Aggregate Earnings
2019				
Occupational Total	165,694,988	$8,039,931		
Non-STEM	156,565,812	7,221,072	94.49%	89.82%
STEM Total	9,129,177	818,859	5.51	10.18
Computer	5,152,925	479,201	3.11	5.96
Math	206,739	18,766	0.12	0.23
Engineering	2,021,707	202,915	1.22	2.52
Engineering Technician	718,191	41,488	0.43	0.52
Science	684,276	59,614	0.41	0.74
Science Technician	345,339	16,875	0.21	0.21
Industrial Total	165,694,988	11,444,854		
Non-STEM	157,732,217	10,312,686	95.19	90.11
STEM Total	7,962,772	1,132,168	4.81	9.89
Manufacturing	1,975,657	287,557	1.19	2.51
Services	5,987,114	844,611	3.61	7.38
Change**				
Occupational Total	11.3%	20.2%		
Non-STEM	10.4	18.0	-0.83	-1.70
STEM Total	31.1	44.3	0.83	1.70
Computer	46.4	64.5	0.74	1.61
Math	105.8	121.2	0.06	0.11
Engineering	20.7	24.4	0.09	0.09
Engineering Technician	-13.2	-10.7	-0.12	-0.18
Science	29.6	37.6	0.06	0.09
Science Technician	10.7	13.7	-0.00	-0.01
Industrial Total	14.0	31.1		
Non-STEM	13.8	29.0	-0.18	-1.44
STEM Total	18.4	53.3	0.18	1.44
Manufacturing	-24.8	-1.0	-0.61	-0.82
Services	46.0	88.6	0.79	2.25

* The aggregate earnings figures shown in this table are calculated from employment and earnings per job. The occupational figures are estimates since only median earnings per job are available.
** The percent changes are adjusted for inflation. The change is from 2005 to 2019 for the occupational data and from 2001 to 2019 for the industrial data.

Sources: Emsi (employment and earnings) and U.S. Department of Commerce, Bureau of Economic Analysis (gross domestic product implicit price deflator). Definition of STEM occupations and STEM-intensive industries produced by authors.

TABLE 14
EARNINGS PER JOB IN THE UNITED STATES AND ARIZONA

	United States	Arizona	Ratio of Arizona to Nation*	Arizona Rank*: 51 States	Arizona Rank*: 10 Western States
2019					
Occupational Total	$48,522	$46,611	0.998	29	4
Non-STEM	46,122	44,407	1.000	29	4
STEM Total	89,697	83,603	0.968	23	6
Computer	92,996	85,252	0.952	24	5
Math	90,770	93,124	1.065	7	1
Engineering	100,368	97,737	1.011	18	6
Engineering Technician	57,768	57,488	1.033	24	3
Science	87,120	75,990	0.906	32	6
Science Technician	48,865	43,717	0.929	43	8
Industrial Total	69,072	62,674	0.942	29	5
Non-STEM	65,381	59,531	0.946	35	6
STEM Total	142,183	118,674	0.867	21	6
Manufacturing	145,550	138,528	0.988	10	5
Services	141,072	105,412	0.776	34	9
Change**					
Occupational Total	7.9%	15.3%		4	1
Non-STEM	6.9	14.4		4	1
STEM Total	10.1	15.3		6	3
Computer	12.4	18.8		6	2
Math	7.4	30.8		2	1
Engineering	3.1	4.8		20	5
Engineering Technician	2.8	10.6		8	2
Science	6.2	13.4		6	1
Science Technician	2.7	4.2		27	5
Industrial Total	15.0	19.5		13	4
Non-STEM	13.4	19.9		11	3
STEM Total	29.5	22.5		31	5
Manufacturing	31.6	31.9		18	3
Services	29.2	25.0		21	4

Note: The STEM and non-STEM occupational figures shown in this table are estimates, calculated from employment and median earnings per job in each occupation; the change is from 2005 to 2019. The industrial figures reflect average earnings per job; the change is from 2001 to 2019.

* The figures for Arizona and other states are adjusted for the cost of living.
** Adjusted for inflation and for the change in the cost of living. The 2008 RPP estimates are used for 2001 and 2005.

Sources: Emsi (employment and earnings) and U.S. Department of Commerce, Bureau of Economic Analysis (gross domestic product implicit price deflator and regional price parity). Definition of STEM occupations and STEM-intensive industries produced by authors.

(particularly in the engineering technician category). Though the change in share in the math category was small, the percent change in share was large.

In most of the STEM occupations, the change in share between 2005 and 2019 was slight. The "software developers and software quality assurance analysts and testers" occupation had the largest increase in share based on both employment and aggregate earnings, but this was partially offset by a decline in share in the "computer programmers" occupation. Otherwise, the largest gain in share based on employment was in "computer user support specialists," a relatively low-paying occupation. The second-greatest increase based on aggregate earnings was in miscellaneous computer occupations. A number of the technician occupations experienced a decline in share between 2005 and 2019 based on both employment and aggregate earnings.

As seen in Table 13, the percent change between 2005 and 2019 in employment and aggregate earnings varied widely across the six occupational categories, from more than a doubling in math to a decline in engineering technician. The overall STEM percent change was more than double the non-STEM figure.

Between 2005 and 2019, the inflation-adjusted increase in the median earnings of STEM occupations was 10.1 percent, outpacing the 6.9 percent rise in non-STEM median earnings and the 7.9 percent increase in overall median earnings. The ratio of the STEM median to the non-STEM median rose in each year from 2006 through 2015, but declined in each subsequent year. The rise through 2015 largely was due to the computer category. The decline in the ratio since 2015 was particularly large in the engineering and engineering technician categories.

By STEM category, the inflation-adjusted percent change between 2005 and 2019 in median earnings ranged from 12.4 percent in the computer category to 2.7 percent in the science technician category (see Table 14). The percent change was nearly as low in the engineering technician (2.8 percent) and engineering (3.1 percent) categories. The increase was greater than the non-STEM figure only in the computer and math categories.

Nearly all of the computer and math occupations experienced an increase in inflation-adjusted median earnings between 2005 and 2019, with very large gains in some occupations, such as "computer network architects." However, real median earnings fell in 16 percent of the engineering occupations, 46 percent of the engineering technician occupations, 27 percent of the science occupations, and 44 percent of the science technician occupations.

STEM-Intensive Industries

2019. The 57 STEM-intensive industries accounted for 5.7 percent of Emsi's 993 industries, and for 4.81 percent of the U.S. workforce in 2019. As with the occupational data, STEM's share of total aggregate earnings was much higher, at 9.89 percent of the total.

The STEM-intensive industries can be split into two categories: 20 service industries and 37 manufacturing industries. Though fewer in number, the service industries accounted for three-fourths of the total STEM industrial employment and aggregate earnings. The STEM services share was 3.61 percent of total employment and 7.38 percent of total aggregate earnings, compared to the STEM manufacturing share of 1.19 percent of total employment and 2.51 percent of total aggregate earnings.

The eight largest STEM-intensive industries were in the services category. The industry with the most workers, “computer systems design services,” accounted for 1.32 percent of total aggregate earnings, only a slightly greater share than the “custom computer programming services” industry. Of the STEM-intensive manufacturing industries, the share of the total workforce was less than 0.05 percent in 81 percent; only 30 percent of the services industries were this small.

Taken as a whole, the 57 STEM-intensive industries in 2019 had average earnings of $142,183 — 105.8 percent higher than the overall U.S. figure of $69,072. Compared to the average of non-STEM industries ($65,381), the STEM average earnings figure was 117.5 percent higher. Little difference in average earnings was present between the STEM manufacturing category ($145,550) and the STEM services category ($141,072).

In 2019, average earnings in some STEM-intensive industries was more than three times the non-STEM figure:

- Electronic computer manufacturing
- Software publishers
- Internet publishing and broadcasting and Web search portals
- Research and development in biotechnology

The average was at least 2.5 times as high in several other STEM-intensive industries. In contrast, average earnings in the “drafting services” industry was marginally less than the non-STEM figure and some of the other STEM-intensive industries had an earnings premium of less than 25 percent relative to the non-STEM average.

Change Over Time. Between 2001 and 2019, the share of total employment in STEM-intensive industries rose slightly, from 4.63-to-4.81 percent (a 4 percent increase). The increase in share was greater for aggregate earnings, from 8.46-to-9.89 percent (a 17 percent rise).

Based on annual data, the industrial STEM share fell slightly during the early 2000s, but generally increased in succeeding years, based on both employment and aggregate earnings. Thus, the increase in STEM share, of both employment and aggregate earnings, was greater between 2005 and 2019 than between 2001 and 2019. The 2005-to-2019 change in share of total employment was 0.66 percentage points based on the industrial data, a little less than the 0.83 percentage-point increase based on the occupational data. In contrast, the industrial change in share of total aggregate earnings of 2.23 percentage points exceeded the occupational gain of 1.70 percentage points.

A significant difference in the trend was present between the STEM manufacturing category, which experienced a decline in share in most years, and the STEM services category. The share in the latter dropped between 2001 and 2003, but rose in each subsequent year.

In many of the STEM-intensive industries, the change in share between 2001 and 2019 was slight. Three of the largest STEM-intensive industries had a sizable gain in share of aggregate earnings: “Internet publishing and broadcasting and Web search portals,” “computer systems design services,” and “custom computer programming services.”

A substantial percent increase occurred between 2001 and 2019 in employment and aggregate earnings in the services category. In contrast, declines occurred in the manufacturing category. The overall industrial STEM percent change was greater than the non-STEM figure.

Between 2001 and 2019, the inflation-adjusted increase in the average earnings of STEM-intensive industries was 29.5 percent, considerably greater than the 13.4 percent gain in non-STEM industries and the 15.0 percent overall increase. The ratio of the STEM average to the non-STEM average rose in most years from 2002 through 2019. Similar gains were experienced in the STEM manufacturing (31.6 percent) and services (29.2 percent) categories. Only 5 percent of STEM-intensive industries experienced a decrease in real average earnings, while 44 percent had a real gain of at least 25 percent.

STEM Economic Activity by State

The STEM share in 2019 by state can be calculated in four ways: occupational employment, occupational aggregate earnings, industrial employment, and industrial aggregate earnings. The number of states with a share equal to or greater than the national average ranges from only 11 to 18 across the four measures. Twenty-four states had a share at least equal to the national average in at least one of the four measures.

Seven states stand out as ranking in the top 10 on all four measures: California, Colorado, Maryland, Massachusetts, Utah, Virginia, and Washington. In three of the four measures, Arizona, the District of Columbia, New Hampshire, New Mexico, and Oregon at least matched the U.S. share. Delaware, Michigan, and Minnesota at least matched the U.S. average in both of the occupational measures. These 15 states are distributed by region, as defined by the Census Bureau, as follows:

- Three of the five Pacific states, including each of the mainland states.
- Four of the eight Mountain states, all contiguous in the southeast portion of the region.
- One of seven West North Central states.
- One of five East North Central states.
- Two of six New England states.
- None of the three Middle Atlantic states.
- Four of the nine South Atlantic states, all contiguous in the northeast portion of the region.
- None of the four East South Central states.
- None of the four West South Central states.

Thus, states with a high STEM share in 2019 are disproportionately located in three parts of the country: the West Coast, Utah-Colorado-New Mexico-Arizona, and Delaware-Maryland-District of Columbia-Virginia.

Nine of the 15 states ranking among the leaders on the 2019 STEM share also rank high on the change over time in the STEM share: California, Colorado, Maryland, Massachusetts, Michigan, New Hampshire, Utah, Virginia, and Washington. Other states performing strongly on the change in STEM share include Missouri, North Carolina, Ohio, South Carolina, and Wisconsin.

The actual occupational STEM share of employment by state in 2019, and the change in share between 2005 and 2019, is displayed in the left portion of Table 15. The states are listed in order of the 2019 STEM share of total employment. The middle portion of the table displays what the shares would have been if each metro area in a state had a STEM share equal to its size-class average, if the nonmetro area of each state had a share equal to the U.S. nonmetro area average, and if the "county not reported" category had a share equal to its national average.[21]

A comparison of these "expected" shares to the actual shares provides a better measure of a state's STEM performance than the actual figures because the "expected" figures take into consideration the wide differences across states in the settlement pattern and in the differences in STEM share by metropolitan size/nonmetro area/"county not reported," discussed later in this chapter. Based on the relationship between STEM intensity and size of the labor market, a state such as South Dakota, which does not have a metro area in the first three size classes, cannot be expected to have as high a STEM share as neighboring Minnesota, in which 65 percent of the state's employment is in the largest size class.

The right portion of Table 15 subtracts the expected share from the actual share. The actual value in 2019 was greater than the expected share in 29 states, including eight of the top 10 states based on the actual 2019 share. Colorado, the District of Columbia, Maryland, Massachusetts, Utah, Virginia, and Washington each had an actual share substantially greater than expected. In contrast, California's high actual share in 2019 was only slightly greater than expected, given its large number of very populous metro areas. States not highly ranked based on the actual 2019 share whose actual value substantially exceeded the expected value include Alaska, Idaho, Montana, New Mexico, and Vermont. In contrast, in some states, the actual share was considerably less than expected, including Florida, Hawaii, Louisiana, Mississippi, Nevada, New York, and Tennessee.

A summary by region of the difference between the actual and expected shares in 2019 follows:

- Pacific: Four of the five states had an actual value greater than expected, with Washington ranked first, and Alaska ninth, on the differential. Hawaii ranked 46th.
- Mountain: Six of the eight states had an actual value greater than expected, with Colorado, New Mexico, and Utah ranked among the top 11. The exceptions were Nevada, which ranked last on the differential, and Arizona, which ranked 36th.
- West North Central: Six of the seven states had an actual value greater than expected, though the differential was slight except in Iowa. Missouri was the only state with a subpar actual value.
- East North Central: Of the five states, only Michigan and Wisconsin had an actual value greater than expected. Illinois ranked in the bottom 10.
- New England: Of the six states, only Rhode Island did not have an actual value greater than expected. Massachusetts, New Hampshire, and Vermont ranked in the top 10.

[21] For those metro areas whose boundaries extend across more than one state, the STEM shares were calculated separately for the portion in each state.

TABLE 15
OCCUPATIONAL STEM SHARE OF EMPLOYMENT BY STATE

	Actual, 2019		Actual, 2005-19 Change		Expected, 2019*		Expected, 2005-19 Change*		Actual Minus Expected, 2019		Actual Minus Expected, 2005-19 Change	
	Rank	Share	Rank	Share	Rank	Share	Rank	Share	Rank	Share	Rank	Share
District of Columbia	1	9.01%	28	0.66	1	6.44%	10	0.88	1	2.57	36	-0.22
Maryland	2	8.47	5	1.20	3	6.32	1	0.99	4	2.15	12	0.22
Washington	3	8.00	1	1.60	14	5.54	20	0.78	2	2.46	1	0.82
Virginia	4	7.93	4	1.21	17	5.52	8	0.89	3	2.41	10	0.33
Massachusetts	5	7.71	2	1.44	5	6.06	13	0.87	7	1.65	2	0.57
Colorado	6	7.46	10	1.06	21	5.36	25	0.75	5	2.10	11	0.31
California	7	6.48	12	0.98	4	6.16	6	0.90	24	0.32	19	0.08
Utah	8	6.46	9	1.08	30	4.77	43	0.53	6	1.68	3	0.55
Michigan	9	6.41	7	1.18	23	5.34	19	0.79	12	1.07	7	0.39
New Hampshire	10	6.39	3	1.23	31	4.75	22	0.77	8	1.64	6	0.46
Minnesota	11	6.00	15	0.93	18	5.51	15	0.85	21	0.49	21	0.08
Connecticut	12	5.95	30	0.59	22	5.36	30	0.71	17	0.59	30	-0.11
Delaware	13	5.91	51	-0.06	12	5.70	27	0.74	28	0.21	51	-0.80
New Jersey	14	5.89	37	0.48	2	6.35	2	0.98	38	-0.46	49	-0.50
Oregon	15	5.84	17	0.86	24	5.27	24	0.76	18	0.57	18	0.09
Arizona	16	5.62	20	0.81	6	5.97	9	0.88	36	-0.35	27	-0.08
Rhode Island	17	5.51	25	0.72	15	5.54	26	0.74	30	-0.03	25	-0.02
New Mexico	18	5.51	42	0.38	38	4.40	37	0.61	11	1.10	38	-0.24
Texas	19	5.49	24	0.73	11	5.80	3	0.93	35	-0.31	34	-0.20
Alaska	20	5.45	43	0.31	45	3.91	47	0.42	9	1.54	29	-0.11
North Carolina	21	5.44	6	1.19	27	5.04	16	0.84	23	0.39	8	0.35
Georgia	22	5.38	21	0.81	16	5.53	5	0.90	31	-0.14	28	-0.10
Ohio	23	5.21	11	1.03	19	5.47	14	0.85	34	-0.26	14	0.18
Pennsylvania	24	5.18	18	0.85	13	5.56	12	0.87	37	-0.37	26	-0.02
Wisconsin	25	5.17	8	1.14	35	4.57	35	0.62	16	0.59	4	0.52
Illinois	26	5.13	27	0.69	8	5.90	4	0.92	43	-0.77	37	-0.23

(continued)

TABLE 15 (continued)
OCCUPATIONAL STEM SHARE OF EMPLOYMENT BY STATE

	Actual, 2019		Actual, 2005-19 Change		Expected, 2019*		Expected, 2005-19 Change*		Actual Minus Expected, 2019		Actual Minus Expected, 2005-19 Change	
	Rank	Share	Rank	Share	Rank	Share	Rank	Share	Rank	Share	Rank	Share
Idaho	27	5.02%	45	0.21	41	4.02%	41	0.56	13	1.00	41	-0.35
Missouri	28	4.98	14	0.95	20	5.45	17	0.84	39	-0.48	17	0.11
Alabama	29	4.91	29	0.60	39	4.35	38	0.61	20	0.56	24	-0.01
Vermont	30	4.79	31	0.57	47	3.55	45	0.52	10	1.24	23	0.05
Nebraska	31	4.75	26	0.72	36	4.50	39	0.59	26	0.25	16	0.13
Kansas	32	4.75	34	0.51	33	4.68	29	0.71	29	0.07	33	-0.20
Iowa	33	4.57	13	0.96	43	3.93	46	0.49	15	0.64	5	0.47
New York	34	4.54	33	0.53	7	5.93	7	0.89	48	-1.39	44	-0.36
Indiana	35	4.46	19	0.83	26	5.09	23	0.77	40	-0.62	22	0.06
Oklahoma	36	4.40	36	0.49	34	4.64	36	0.61	33	-0.24	31	-0.12
South Carolina	37	4.39	16	0.89	28	5.02	28	0.73	41	-0.63	15	0.17
Montana	38	4.28	38	0.47	50	3.33	50	0.39	14	0.95	20	0.08
Maine	39	4.27	22	0.75	42	3.99	40	0.56	25	0.28	13	0.19
Florida	40	4.13	35	0.51	9	5.86	11	0.87	50	-1.74	43	-0.36
Tennessee	41	3.91	32	0.53	25	5.19	21	0.78	47	-1.29	40	-0.25
Hawaii	42	3.90	49	0.09	29	4.83	42	0.54	46	-0.93	48	-0.45
North Dakota	43	3.86	47	0.13	49	3.46	51	0.38	22	0.40	39	-0.25
Wyoming	44	3.77	50	0.07	51	3.20	48	0.42	19	0.57	42	-0.35
South Dakota	45	3.74	23	0.73	48	3.49	49	0.39	27	0.25	9	0.34
West Virginia	46	3.72	40	0.44	46	3.91	31	0.66	32	-0.20	35	-0.21
Kentucky	47	3.71	39	0.46	37	4.44	33	0.63	42	-0.74	32	-0.17
Arkansas	48	3.34	44	0.24	40	4.12	32	0.65	44	-0.78	46	-0.40
Louisiana	49	3.25	48	0.10	32	4.71	34	0.63	49	-1.46	50	-0.53
Nevada	50	3.25	41	0.41	10	5.83	18	0.82	51	-2.59	47	-0.41
Mississippi	51	2.99	46	0.14	44	3.91	44	0.52	45	-0.92	45	-0.38

* The “expected” share is calculated using the size-class average for each metro area and the national average for the nonmetro area and “county not reported.”

Sources: Emsi (employment). Definition of STEM occupations produced by authors.

- Middle Atlantic: Each of the three states had an actual value less than expected, with New York ranked 48th.
- South Atlantic: Five of the nine states had an actual value greater than expected, with the differential among the top four in the District of Columbia, Maryland, and Virginia. In contrast, Florida ranked second lowest.
- East South Central: Alabama had an actual value greater than expected, but Kentucky, Mississippi, and Tennessee each ranked among the bottom 10.
- West South Central: Each of the four states had an actual value less than expected, with Arkansas and Louisiana ranking among the bottom 10.

The actual change in share between 2005 and 2019 was greater than expected in 23 states. Most of the highly ranked states based on the actual change had an actual change larger than expected. A summary by region of the difference between the actual and expected change in share follows:

- Pacific: The actual change exceeded the expected value in each of the mainland states, with Washington ranking first on the differential. Hawaii ranked 48th.
- Mountain: Only three of the eight states had an actual change greater than expected: Utah (ranked third), Colorado, and Montana. In contrast, Idaho, Nevada, and Wyoming ranked among the bottom 10.
- West North Central: Five of the seven states had an actual change greater than expected, with Iowa and South Dakota ranking in the top 10.
- East North Central: Only Illinois had an actual change less than expected; Wisconsin and Michigan ranked in the top 10.
- New England: Four of the six states had an actual change greater than expected, with Massachusetts and New Hampshire ranking in the top 10.
- Middle Atlantic: Each of the three states had an actual change less than expected, with New Jersey and New York ranking in the bottom 10.
- South Atlantic: Four of the nine states had an actual change greater than expected: Maryland, North Carolina, South Carolina, and Virginia, with each ranking in the top 15. In contrast, Delaware and Florida ranked in the bottom 10.
- East South Central: None of the four states had an actual change greater than expected, with Mississippi ranking among the bottom 10.
- West South Central: Each of the four states had an actual change less than expected, with Arkansas and Louisiana ranking among the bottom 10.

The "STEM Economic Activity by State" paper, available from https://economist.asu.edu/p3-productivity-prosperity-project/knowledge-economy/, provides more information by state and for the metro areas in each state.

STEM Economic Activity in Arizona

In this section, Arizona is compared to the nation, to all states, and to a set of 10 western states: Arizona, California, Colorado, Idaho, Nevada, New Mexico, Oregon, Texas, Utah, and Washington.

Based on the actual STEM share of occupational/industrial employment/aggregate earnings in 2019, Arizona is a second-tier state nationally, ranking 16th and 18th on the two occupational measures and 11th and 13th on the two industrial measures. Arizona ranked 20th on the occupational change in share between 2005 and 2019 on each measure. However, the state's ranks on the two industrial measures were 44th and 47th on the change between 2001 and 2019.

Arizona compares less favorably among the 10 western states. It ranked sixth or seventh among the 10 states on the four measures of 2019 share and between fifth and ninth on the four measures of the change in share. In 2019, the share in Arizona was less on each measure than in California, Colorado, Utah, and Washington and more on each measure than in Idaho and Nevada. The change in share over time on each measure was less in Arizona than in California, Utah, and Washington and more in Arizona than in Idaho.

Based on occupational employment, Arizona's actual STEM share in 2019 was 0.35 percentage points less than the expected value, ranking 36th. The actual change in share between 2005 and 2019 also was less than expected, by 0.08 percentage points, ranking 27th. Arizona ranked ninth among the western states on the differential between the actual and expected share in 2019, besting only Nevada. Texas was the only other western state to have an actual value less than expected. On the differential between the actual and expected change in share between 2005 and 2019, Arizona ranked sixth among the western states, ahead of Texas, New Mexico, Idaho, and Nevada. The actual change exceeded the expected change in the other five western states.

Table 16 provides an employment and aggregate earnings summary for Arizona for 2019 and for the change over time based on both the occupational and industrial datasets. It is the counterpart of the national data shown in Table 13. Earnings per job figures for Arizona are in Table 14.

STEM Occupations in Arizona

2019. Based on the occupational data, Arizona's STEM share of aggregate earnings was 10.08 percent in 2019, marginally less than the national share of 10.18 percent. Arizona ranked 18th among all states but only seventh among the 10 western states. Five western states ranked among the nation's top 10. Arizona's occupational STEM share of employment in 2019 was 5.62 percent, a little higher than the national figure of 5.51 percent. Arizona ranked 16th among all states and sixth among the western states.

In Arizona in 2019, the computer occupations accounted for 60 percent of the STEM employment and 61 percent of the STEM aggregate earnings. The occupations of the engineering category accounted for 21 percent of STEM employment and 24 percent of the STEM aggregate earnings. The other four categories combined were responsible for 19 percent of STEM employment and only 15 percent of STEM aggregate earnings.

Relative to the nation, Arizona's STEM activities in 2019 were proportionately larger in the computer and engineering technician categories and relatively smaller in the engineering, science, and science technician categories. Below, Arizona's 2019 ranks by occupational category are shown in the following order: aggregate earnings among the 51 states, employment among the 51 states, aggregate earnings among the 10 western states, and employment among the 10 western states:

- Computer: 14, 13, 5, 5
- Math: 14, 18, 2, 3
- Engineering: 24, 28, 9, 9

TABLE 16
STEM EMPLOYMENT AND AGGREGATE EARNINGS IN ARIZONA

			STEM Share of Total		Difference in STEM Share From Nation		Rank Among 51 States		Rank Among 10 Western States	
	Employment	Aggregate Earnings in Millions*	Employment	Aggregate Earnings	Employment	Aggregate Earnings	Employment	Aggregate Earnings	Employment	Aggregate Earnings
2019										
Occupational Total	3,247,778	$151,382								
Non-STEM	3,065,174	136,116	94.38%	89.92%	-0.11	0.10				
STEM Total	182,604	15,266	5.62	10.08	0.11	-0.10	16	18	6	7
Computer	110,086	9,385	3.39	6.20	0.28	0.24	13	14	5	5
Math	4,032	375	0.12	0.25	-0.00	0.01	18	14	3	2
Engineering	37,495	3,665	1.15	2.42	-0.07	-0.10	28	24	9	9
Engineer Technician	17,558	1,009	0.54	0.67	0.11	0.15	7	8	4	4
Science	7,572	575	0.23	0.38	-0.18	-0.36	51	50	10	10
Science Technician	5,861	256	0.18	0.17	-0.03	-0.04	38	46	10	10
Industrial Total	3,247,778	203,552								
Non-STEM	3,075,157	183,066	94.68	89.94	-0.51	-0.17				
STEM Total	172,621	20,486	5.32	10.06	0.51	0.17	13	11	7	7
Manufacturing	69,134	9,577	2.13	4.70	0.94	2.19	6	5	3	4
Services	103,488	10,909	3.19	5.36	-0.43	-2.02	17	22	7	8

(continued)

TABLE 16 (continued)
STEM EMPLOYMENT AND AGGREGATE EARNINGS IN ARIZONA

			STEM Share of Total		Difference in STEM Share From Nation		Rank Among 51 States		Rank Among 10 Western States	
	Employ-ment	Aggregate Earnings in Millions*	Employ-ment	Aggre-gate Earnings	Employ-ment	Aggre-gate Earnings	Employ-ment	Aggre-gate Earnings	Employ-ment	Aggre-gate Earnings
Change**										
Occupational Total	16.5%	28.5%								
Non-STEM	15.5	26.5	-0.81	-1.45	0.02	0.25				
STEM Total	36.1	50.1	0.81	1.45	-0.02	-0.25	20	20	6	5
Computer	65.6	88.2	1.00	1.97	0.26	0.36	7	10	5	4
Math	161.9	228.0	0.07	0.15	0.01	0.04	14	7	3	1
Engineering	12.6	13.0	-0.04	-0.33	-0.13	-0.41	48	48	10	10
Engineer Technician	-18.4	-13.6	-0.23	-0.32	-0.11	-0.15	51	51	10	10
Science	23.5	34.1	0.01	0.02	-0.04	-0.08	37	30	7	6
Science Technician	12.1	11.8	0.00	-0.03	0.00	-0.01	29	35	6	6
Industrial Total	29.4	48.0								
Non-STEM	30.3	49.5	0.62	0.89	0.79	2.33				
STEM Total	16.0	36.0	-0.62	-0.89	-0.79	-2.33	44	47	8	9
Manufacturing	-23.6	-3.5	-1.48	-2.51	-0.86	-1.70	48	49	9	10
Services	77.3	112.2	0.86	1.62	0.07	-0.63	13	15	5	6

Note: The occupational aggregate earnings figures reflect median earnings per job; the change is from 2005 to 2019. The occupational figures shown in this table are estimates, calculated from employment and median earnings per job in each occupation. The industrial figures reflect average earnings per job; the change is from 2001 to 2019.

* The figures for Arizona and other states are adjusted for the cost of living.
** Adjusted for inflation and for the change in the cost of living. The 2008 RPP estimates are used for 2001 and 2005.

Sources: Emsi (employment and earnings) and U.S. Department of Commerce, Bureau of Economic Analysis (gross domestic product implicit price deflator and regional price parity). Definition of STEM occupations and STEM-intensive industries produced by authors.

- Engineering technician: 8, 7, 4, 4
- Science: 50, 51, 10, 10
- Science technician: 46, 38, 10, 10

Taken together, the 10 western states compared favorably in each category except math.

The six largest STEM occupations in 2019 in Arizona were in the computer category. The top-10 list is similar to the national list, except that the electrical engineers occupation is in the top 10 in Arizona instead of the civil engineers occupation.

Taken as a whole, the 81 STEM occupations had median earnings per job of $83,603 in Arizona in 2019 — 79.4 percent higher than the overall figure of $46,611. Compared to the median of non-STEM workers ($44,407), the median of STEM earnings was 88.3 percent higher. The differential between the STEM and non-STEM medians was less in Arizona than the nation. Arizona's non-STEM median earnings figure in 2019 was nearly the same as the nation after adjusting for the cost of living, but the STEM median was 3.2 percent lower than the national average, ranked 23rd among all states and sixth among the western states.

Occupational STEM job quality in Arizona in 2019 was less than the national average, but Arizona ranked 24th among all states and fifth among the western states. By far the largest single reason for the state's below-average occupational STEM job quality in 2019 was its above-average share in the relatively low-paying "computer user support specialists" occupation. After removing the effect of job quality, the balance of median earnings per job adjusted for the cost of living ranked 24th among all states and sixth among the western states in Arizona in 2019.

Arizona's median earnings per job after adjustment for the cost of living was higher than the national median in the math, engineering, and engineering technician categories, but was 5 percent lower in the computer category, 7 percent lower in the science technician category, and 9 percent lower in the science category. The differential varied widely by individual occupation.

Based on the aggregate earnings share in 2019, Arizona ranked second among the 51 states in the relatively low-paying "computer user support specialists" occupation, which was the largest contributor to Arizona's positive differential from the nation in the share of aggregate earnings in the computer category. Other computer occupations on which Arizona had a high rank included the "information security analysts" (rank of eighth) and "software developers, quality assurance analysts, and testers" (rank of 11th). In the engineering category, Arizona ranked in the top 10 in the "electrical engineers" and "electronics engineers" occupations, but had a subpar rank in "civil engineers" and "miscellaneous engineers."

Arizona's lesser share in the science category was due to a slightly smaller share in each occupation. The largest shortfall was in the "medical scientists, except epidemiologists" occupation. Arizona ranked 31st or lower in 16 of the 22 science occupations.

Change Over Time. STEM's share of total aggregate earnings based on the occupational data rose 1.45 percentage points between 2005 and 2019 in Arizona, but this was less than the national gain of 1.70 percentage points. Arizona ranked 20th in the nation and fifth among the western states. The STEM share of total employment rose nearly as much in Arizona (0.81

percentage points) as in the nation (0.83 percentage points). Arizona ranked 20th in the nation and sixth among the western states.

Arizona's gain in share in the computer category was larger than its STEM total and exceeded the national increase in the computer category. Arizona's change in share also was greater than the nation in the math category. In contrast, Arizona lost ground to the nation in each of the other four categories, particularly engineering and engineering technician. Below, Arizona's ranks on the change in STEM share between 2005 and 2019 by occupational category are shown in the following order: aggregate earnings among the 51 states, employment among the 51 states, aggregate earnings among the 10 western states, and employment among the 10 western states:

- Computer: 10, 7, 4, 5
- Math: 7, 14, 1, 3
- Engineering: 48, 48, 10, 10
- Engineering technician: 51, 51, 10, 10
- Science: 30, 37, 6, 7
- Science technician: 35, 29, 6, 6

Taken together, the 10 western states compared favorably only in the computer category. They compared unfavorably in the engineering, engineering technician, and science technician categories.

The "software developers and software quality assurance analysts and testers" occupation had the largest increase in share of aggregate earnings in Arizona between 2005 and 2019, with a gain larger than the national average and ranking eighth among the states. This was partially offset by a decline in share in the "computer programmers" occupation, but the decrease was not as large as in the nation and Arizona ranked 12th. Large increases also occurred in the "computer and information systems managers" occupation (Arizona ranked 11th) and in "miscellaneous computer occupations" (Arizona ranked 12th), each with an increase slightly greater than the nation. The increase in the "information security analysts" occupation was larger in Arizona than the nation, with Arizona ranked seventh.

Several occupations caused the state's decline in the engineering share. Arizona ranked among the bottom 10 states in the "architectural and engineering managers," "aerospace engineers," "civil engineers," "computer hardware engineers," "electrical engineers," and "miscellaneous engineers" occupations. However, the share in the "industrial engineers" occupation rose in Arizona, keeping pace with the nation.

Nearly every occupation in the engineering technician category contributed to the state's sizable decrease in aggregate earnings share. Arizona ranked among the bottom 10 states in most of these occupations.

The overall occupational percent change in STEM employment between 2005 and 2019 was 36.1 percent in Arizona, somewhat higher than the U.S. increase of 31.1 percent. Arizona's increase in non-STEM employment also exceeded the national average (15.5-versus-10.4 percent). Gains in Arizona were considerably greater than the national average in the computer and math categories. In contrast, Arizona lagged behind the nation in the engineering, engineering technician, and science categories.

Between 2005 and 2019, the increase in the median earnings per job of non-STEM occupations — adjusted for inflation and the change in the cost of living — was greater in Arizona (9.4 percent) than in the nation (6.9 percent). The differential was not as large in the STEM occupations, with a gain of 10.4 percent in Arizona and 10.1 percent in the nation; Arizona ranked 19th among all states and fourth among the 10 western states.

Occupational STEM job quality increased slightly more in Arizona than the nation between 2005 and 2019. Arizona ranked 13th among all states and third among the western states on the change in job quality. Employment gains in the relatively low-paying "computer user support specialists" occupation had a significant downward influence on the change in job quality. After removing the effect of job quality, the change between 2005 and 2019 in the balance of median earnings per job adjusted for the cost of living ranked 10th among all states and third among the western states.

By STEM category, the percent change between 2005 and 2019 in median earnings — adjusted for inflation and the change in the cost of living — was higher in Arizona than the nation in each category, with a particularly large difference in the small math category.

STEM-Intensive Industries in Arizona

2019. Based on the industrial data, Arizona's STEM share of aggregate earnings was 10.06 percent in 2019, a little higher than the national share of 9.89 percent. Arizona ranked 11th among all states but only seventh among the 10 western states. The state's STEM industrial employment share was 5.32 percent compared to the national average of 4.81 percent. Arizona ranked 13th among all states but only seventh among the 10 western states. Taken together, the western states compared favorably overall, and in the manufacturing and services categories.

In Arizona in 2019, the manufacturing occupations accounted for 40 percent of the STEM employment and 47 percent of the STEM aggregate earnings, shares well above those of the nation. Relative to the nation, Arizona's industrial STEM activities in 2019 were proportionately much larger in the manufacturing category and relatively smaller in the services category. The state's industrial STEM aggregate earnings share in the manufacturing category was 4.70 percent, much higher than the national average of 2.51 percent. Among all states, Arizona ranked fifth in the manufacturing category, though only fourth among the 10 western states. Based on employment, Arizona's share of 2.13 percent also was well above the U.S. average of 1.19 percent. Arizona ranked sixth nationally and third among the western states.

In the services category, Arizona's share of aggregate earnings of 5.36 percent was considerably less than the national share of 7.38 percent. Despite its share being much below the U.S. average, Arizona ranked 22nd among all states, though only eighth among the western states. Based on employment, Arizona's services share of 3.19 percent was not as far below the U.S. average of 3.61 percent. Arizona ranked 17th in the nation but only seventh among the western states.

The two largest STEM-intensive industries in 2019 were in the manufacturing category, with services industries ranking from third through seventh. This top-10 list is very different than the national list, in which the eight largest STEM-intensive industries were in the services category.

Taken as a whole, the 57 STEM-intensive industries had average earnings per job of $118,674 in Arizona in 2019 — 89.4 percent higher than the overall figure of $62,674. Compared to the average of non-STEM workers ($59,531), the mean of STEM earnings was 99.3 percent higher. The differential between the STEM and non-STEM means was not as large in Arizona as the nation. Arizona's non-STEM mean earnings per job in 2019 was 5.4 percent less than the national average after adjusting for the cost of living, but the STEM mean was 13.3 percent below average.

Industrial STEM job quality in Arizona in 2019 was considerably stronger than the national average. Arizona ranked eighth among all states, but only sixth among the 10 western states. The mix of STEM-intensive industries in Arizona in 2019 was much different than the national average. A high share of employment in two high-paying industries— "semiconductor and related device manufacturing" and "guided missile and space vehicle manufacturing" — was responsible for Arizona's strong showing.

Arizona's adjusted average earnings per job in the manufacturing category was lower than the national average by only 1.2 percent, as the state's high percentage of manufacturing in the two high-paying industries almost offset the state's lower average earnings in most STEM-intensive manufacturing industries — Arizona's adjusted figure was at least 20 percent below the nation in 19 of the 37 STEM-intensive manufacturing industries. Arizona's adjusted average earnings per job in the services category was 22.4 percent below the national average. As in the manufacturing category, the adjusted average earnings figures in half of the industries in the services category were at least 20 percent below the U.S. average, but this was not offset by a large share of the services activity being in high-paying industries.

Arizona ranked in the top 10 among all states in several manufacturing industries, including "semiconductor and related device manufacturing" and five of the six industries in the "aerospace product and parts" industry group. The share of aggregate earnings in Arizona was far above the U.S. average in the "semiconductor and related device manufacturing" and "guided missile and space vehicle manufacturing" industries. The combined share of the other 35 STEM-intensive manufacturing industries was less than the national average.

In 14 of the 20 services industries, the share of aggregate earnings in Arizona was slightly greater than the national average. However, Arizona had considerably smaller shares in six industries: "software publishers," "Internet publishing and broadcasting and Web search portals," "custom computer programming services," computer systems design services," "research and development in biotechnology," and "research and development in other physical, engineering, and life sciences." Despite the below-average share, Arizona ranked in the top 25 states in five of these six industries. In general, the nation's STEM-intensive industrial activity is highly concentrated in relatively few states.

Change Over Time. The STEM-intensive industry share of total aggregate earnings fell 0.89 percentage points between 2001 and 2019 in Arizona, in sharp contrast to a gain of 1.44 percentage points in the nation. Arizona's change ranked 47th among all states and ninth among the western states. Arizona's performance was not quite as negative based on employment, with a decrease of 0.62 percentage points compared to the U.S. average gain of 0.18 percentage points. Arizona ranked 44th nationally and eighth among the western states.

In the manufacturing category, Arizona's share of aggregate earnings declined 2.51 percentage points between 2001 and 2019, a larger loss than the national average of 0.82 percentage points. Arizona ranked 49th among all states and last among the western states. Based on the change in the employment share, the results were similar. The share fell 1.48 percentage points in Arizona compared to a drop of 0.61 percentage points nationally. Arizona ranked 48th among all states and ninth among the western states.

While the share of aggregate earnings in the services category rose 1.62 percentage points in Arizona and ranked 15th among the states, the increase was short of the national average of 2.25 percentage points. Arizona ranked only sixth among the western states. Based on employment, Arizona's ranks were similar — 13th nationally and fifth among the western states, but the change in share of 0.86 percentage points slightly exceeded the national gain of 0.79 percentage points.

The share of aggregate earnings fell between 2001 and 2019 in 20 of the 37 manufacturing industries in Arizona, though the change was inferior to the nation in only 12 industries. The share of the "semiconductor and related device manufacturing" industry dropped 1.48 percentage points in Arizona much more than the decrease of 0.12 percentage points nationally between 2001 and 2019. This one industry in Arizona accounted for 59 percent of the manufacturing category's overall decrease and for 80 percent of the shortfall in the change from the national average; Arizona ranked 50th among all states and last among the western states. The three aircraft manufacturing industries also contributed to Arizona's inferior performance in the manufacturing category. Combined, the three industries experienced a decline in share of 0.40 percentage points in Arizona, compared to a drop of only 0.03 percentage points nationally. In each of the three aircraft industries, Arizona's change in share ranked between 47th and 51st nationally and between eighth and 10th among the western states.

Among the 20 STEM-intensive services industries, the share of aggregate earnings fell between 2001 and 2019 in only five in Arizona, though the change was inferior to the nation in nine industries. The "Internet publishing and broadcasting and Web search portals" industry accounted for 63 percent of the shortfall from the nation in the services category. Yet Arizona ranked 11th nationally in this industry and fourth among the western states.

The overall industrial percent change in STEM employment between 2001 and 2019 was 16.0 percent in Arizona, somewhat less than the U.S. increase of 18.4 percent. In contrast, Arizona's increase in non-STEM employment considerably exceeded the national average (30.3-versus-13.8 percent). Gains in Arizona were considerably greater than the national average in the services category; the decrease in the manufacturing category was nearly as large as the national average.

Between 2001 and 2019, the increase, adjusted for inflation and the cost of living, in the average earnings per job of non-STEM industries was greater in Arizona (19.9 percent) than in the nation

(13.4 percent). However, the adjusted percent change in the STEM-intensive industries of 22.5 percent in Arizona was less than the national figure of 29.5 percent.

The change in STEM industrial job quality in Arizona between 2001 and 2019 was less than the national average, but Arizona ranked 19th among all states. Arizona ranked sixth on the change in job quality among the western states. Arizona's inferior performance largely resulted from subpar changes in employment in two very high-paying industries: "electronic computer manufacturing" and "Internet publishing and broadcasting and Web search portals."

The adjusted percent change between 2001 and 2019 in average earnings per job in Arizona was less than the national average in the services category and similar to the nation in the manufacturing category. The increase was larger in manufacturing than services.

Time Series of STEM-Intensive Industries and STEM Occupations

The time series of the STEM share of aggregate earnings is displayed in the first graph of Chart 4 for Arizona and the nation based on both the occupational and industrial data. Using the occupational data, the STEM shares rose from 2005 through 2019 in Arizona and the nation, with the STEM share in Arizona quite close to the national figure in each year. Arizona went from marginally above the nation in 2005 to marginally below in 2019.

Based on the industrial data, the STEM share of aggregate earnings dropped in the early 2000s nationally and in Arizona. Nationally, the industrial STEM share climbed more rapidly than the occupational STEM share between 2005 and 2019. Arizona's industrial STEM share relative to the nation decreased from 2001 through 2007 and again from 2011 through 2019. In 2001, Arizona's industrial share was much higher than the national figure, but by 2019 the differential had become quite small.

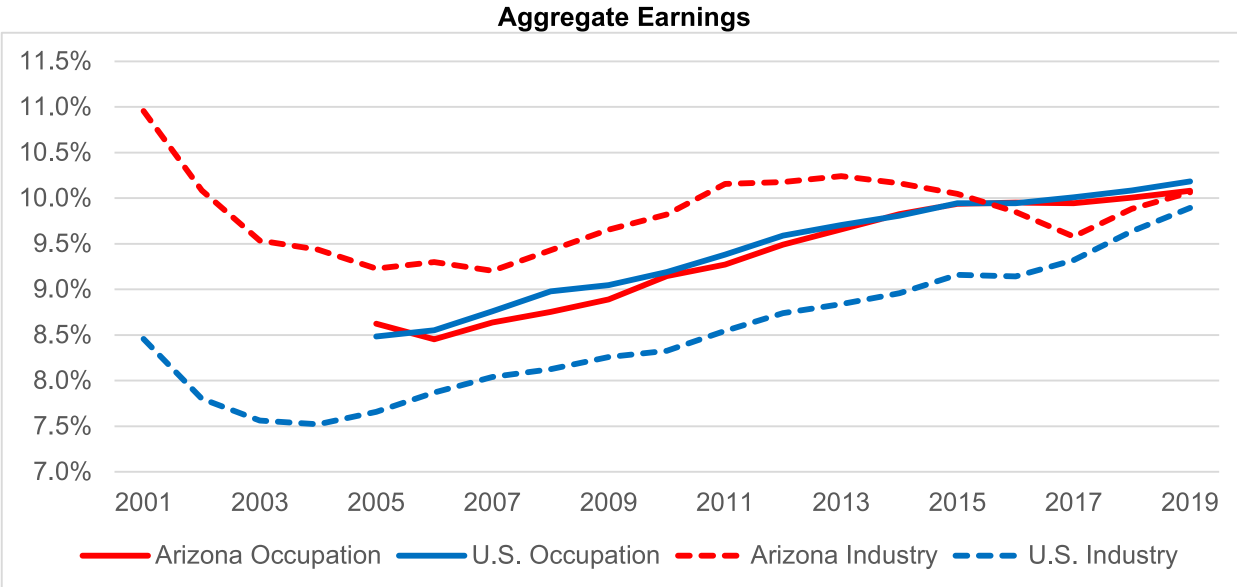
The second graph of Chart 4 displays the STEM employment share. As with aggregate earnings, the occupational share has been similar in Arizona and the nation throughout the time span, but the magnitude of the state's positive differential has narrowed slightly over time. The state's positive differential in the STEM industrial share narrowed more between 2001 and 2017, but grew a bit in 2018 and 2019.

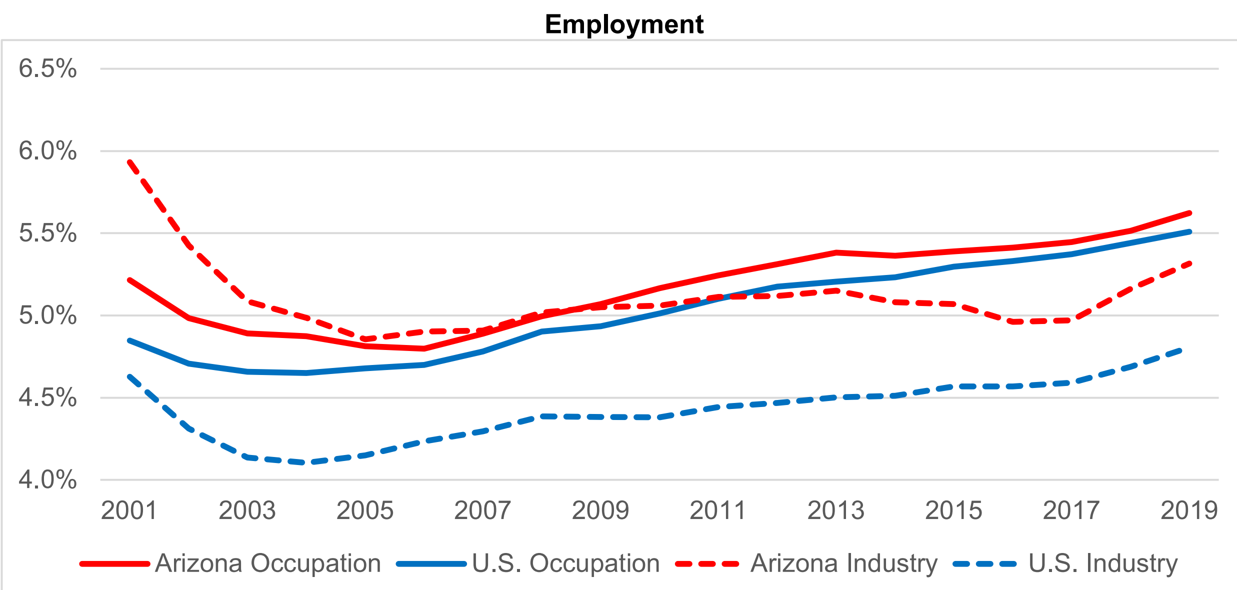
Based on aggregate earnings, the STEM occupational shares in the two largest categories are displayed in the first graph of Chart 5. In the computer category, Arizona's share has climbed a little relative to the nation, going from slightly lower to slightly higher. The opposite has occurred in the engineering category.

Arizona's slight improvement relative to the nation in the math category has occurred since 2016. Arizona's positive differential from the nation in the engineering technician category has gradually narrowed since 2006. The state's shortfall in the science category has not changed much. The small deficiency in the science technician category also has not changed much over time.

The STEM industrial data based on aggregate earnings are split into the manufacturing and services categories in the second graph of Chart 5. Arizona's STEM share has slipped relative to

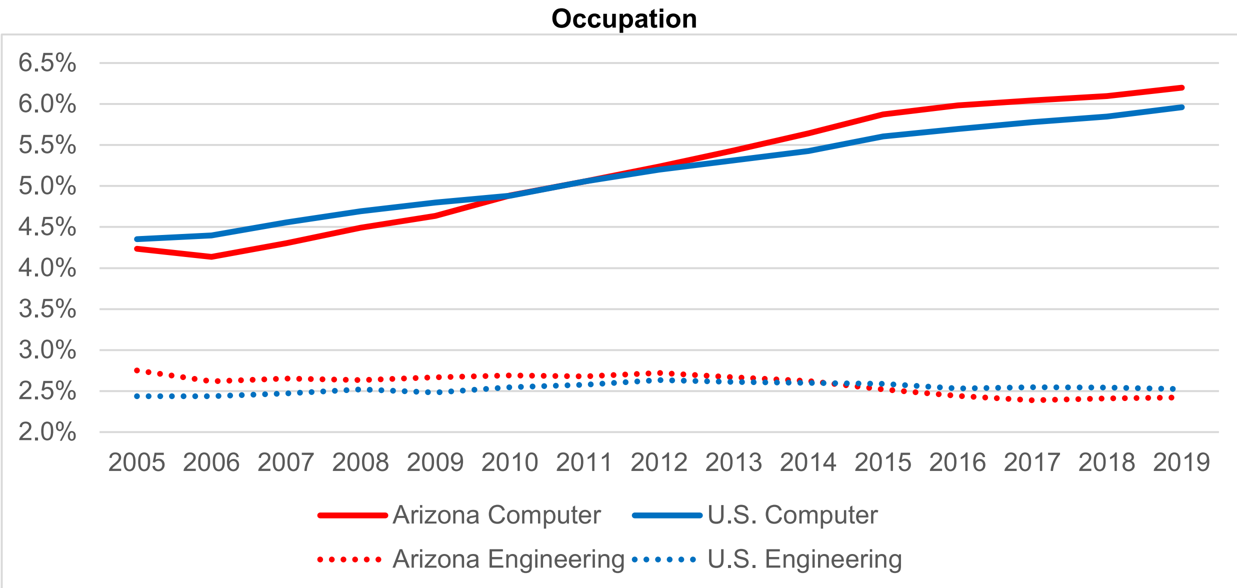
CHART 4
STEM EMPLOYMENT AND AGGREGATE EARNINGS
AS A SHARE OF TOTAL EMPLOYMENT AND AGGREGATE EARNINGS
IN ARIZONA AND THE UNITED STATES

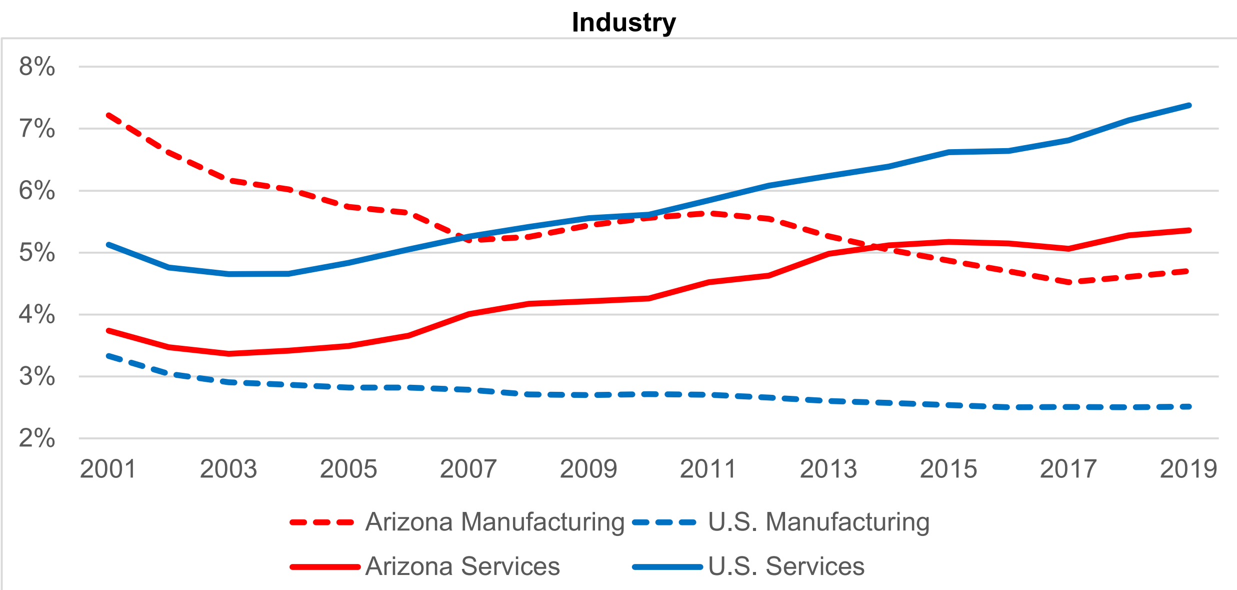




Source: Emsi (employment and earnings). Definition of STEM occupations and STEM-intensive industries produced by authors.

CHART 5
STEM AGGREGATE EARNINGS BY CATEGORY AS A SHARE OF TOTAL AGGREGATE EARNINGS IN ARIZONA AND THE UNITED STATES





Source: Emsi (employment and earnings). Definition of STEM occupations and STEM-intensive industries produced by authors.

the nation in both categories, but especially in manufacturing. Arizona's shortfall to the nation on the share of aggregate earnings in the services category has become larger since 2013, going from -1.26 percent to -2.02 percent in 2019. Arizona's manufacturing share fell relative to the nation from 2001 through 2007, dropping from 3.89-to-2.41 percent higher than the nation. Another relative period of decline occurred from 2011 through 2017, with the share falling from 2.93-to-2.01 percent higher than the nation. The differential widened modestly in 2018 and 2019.

The top graph of Chart 6 displays occupational STEM median earnings. Before adjustment for the cost of living, Arizona's figure fluctuated between 6-and-9 percent below the national figure between 2005 and 2019. Adjusting for the cost of living, Arizona's median rose from 10 percent below the national average in 2008 to 4 percent below in 2011. The differential has been 3-to-4 percent since then. Each category except science technician has contributed to the improvement in Arizona's overall occupational median earnings per job adjusted for the cost of living relative to the nation.

In contrast, Arizona's industrial STEM average earnings has fallen in recent years relative to the nation (see the second graph of Chart 6). Between 2002 and 2011, Arizona's unadjusted figure was 5-to-7 percent below the nation. Since then, the differential has increased to 16 percent. Adjusted for the cost of living, Arizona's figure fell from 3 percent below average in 2011 to 13 percent below average in 2019. The decrease over time in Arizona's overall industrial STEM average earnings per job adjusted for the cost of living relative to the nation is due to a decline in the services category, from 12 percent less in 2009 to 22 percent less in 2018 and 2019. In contrast, adjusted average earnings per job in Arizona in the manufacturing category has fluctuated from 3 percent below to 2 percent above the national figure.

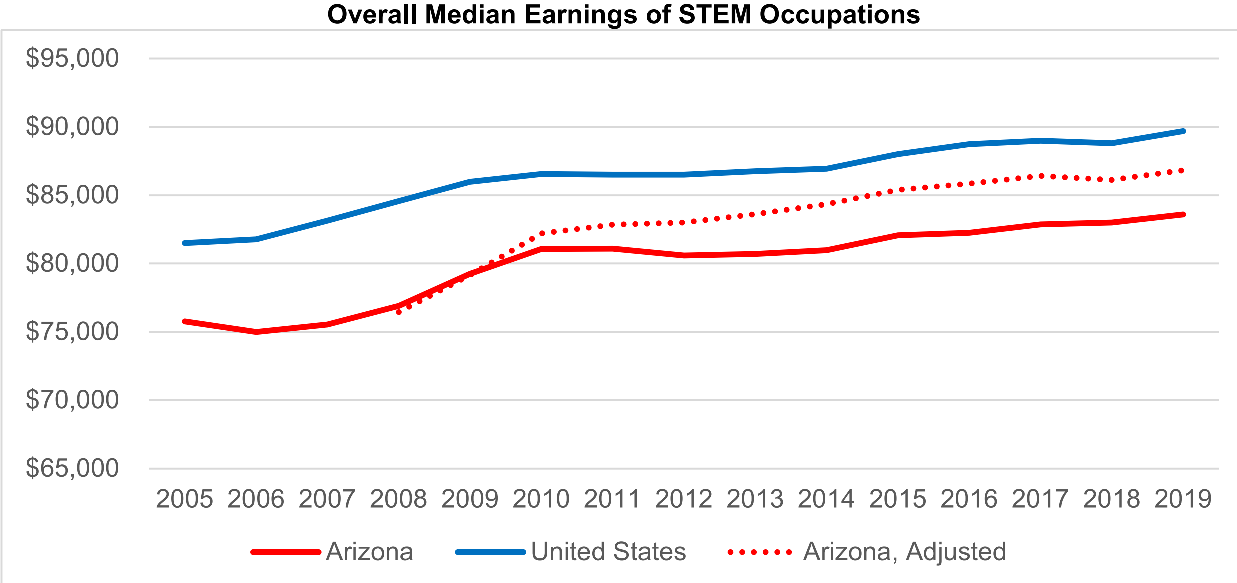
STEM Economic Activity by Metropolitan Area

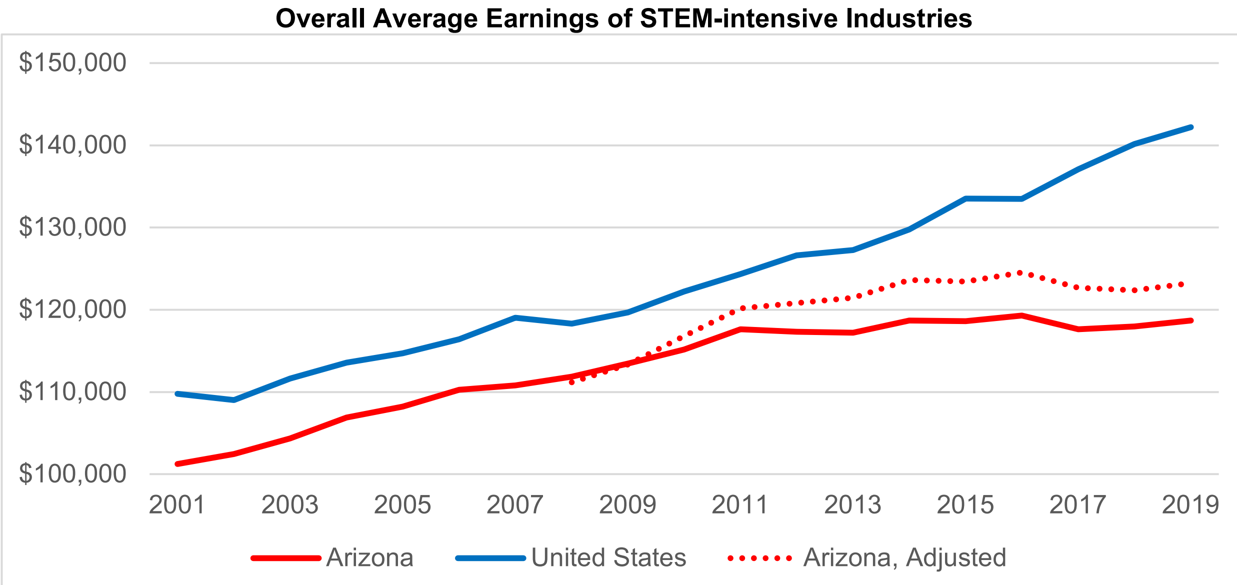
As with the state analysis, the metropolitan analysis adjusts median/mean earnings per job and aggregate earnings for the cost of living. However, the metro analysis focuses on the aggregate earnings measure; the correlation between the aggregate earnings and employment measures is very high across the metro areas.

Prior research revealed that even after adjusting for the cost of living, indicators of prosperity and productivity, such as per capita personal income, are positively correlated with metro size, as measured by population or employment. Similarly, the STEM shares of total aggregate earnings and of total employment are correlated with metro size, as measured by employment and aggregate earnings.

Due to the relationship between metro area size and STEM intensity, instead of comparing each metro area to the average of the 384 metro areas, each metro area is compared to a size-class average. Any number of size classes could be devised. For this analysis of STEM economic activity, the nation's 384 metropolitan areas are grouped into six size classes by the number of workers in 2019. The selection of the size classes was based on a combination of natural breaks in the distribution of 2019 STEM activity as measured by STEM employment and aggregate earnings as a share of the total, and natural breaks in the distribution of 2019 employment, across the metro areas:

CHART 6
INFLATION-ADJUSTED EARNINGS PER JOB
IN ARIZONA AND THE UNITED STATES





Note: The adjusted figures for Arizona use the regional price parity figures from 2008 through 2019 to adjust for the cost of living.

Source: Emsi (earnings) and U.S. Department of Commerce, Bureau of Economic Analysis (GDP implicit price deflator and regional price parity). Definition of STEM occupations and STEM-intensive industries produced by authors.

- 36 metro areas with employment of at least 1 million, accounting for 9.4 percent of the number of metro areas and 58.9 percent of metro area employment. In this paper, this group is referred to as either "the largest size class" or "SC1" (with "SC" the abbreviation for "size class").
- 45 metro areas with employment of between 350,000 and 999,999, accounting for 11.7 percent of metro areas and 16.4 percent of metro area employment. This is "SC2."
- 46 metro areas with employment of between 200,000 and 349,999, accounting for 12.0 percent of metro areas and 8.4 percent of metro area employment. This is "SC3."
- 62 metro areas with employment of between 125,000 and 199,999, accounting for 16.1 percent of metro areas and 6.8 percent of metro area employment. This is "SC4."
- 71 metro areas with employment of between 75,000 and 124,999, accounting for 18.5 percent of metro areas and 4.7 percent of metro area employment. This is "SC5."
- 124 metro areas with employment of less than 75,000, accounting for 32.3 percent of metro areas and 4.7 percent of metro area employment. This is "SC6" or "the smallest size class."

Table 17 summarizes the occupational STEM shares of aggregate earnings by metropolitan size class in 2019 and for the change between 2005 and 2019. The overall STEM share in 2019 was highest in SC1 and declined with size class, being lowest in SC6. The general pattern of decreasing STEM share with decreasing metro size was present in the computer, math, engineering, and science categories. In contrast, in the two technician categories, there was no clear relationship between STEM share and metro size, though the largest size class had the *lowest* shares.

As with the 2019 shares, the change over time in the overall STEM share was related to metro size. Using the occupational data, the greatest increase occurred in SC1, followed by SC2 then SC3. The increases in the three other size classes were similar but less than in SC3. The general pattern of decreasing change in share with decreasing metro size was present in the computer and math categories. In contrast, in the engineering and engineering technician categories, the change in STEM share largely was inversely related to metro size. In the science and science technician categories, there was no clear relationship between the change in STEM share and metro size.

Table 18 provides the same occupational data based on employment, but includes two additional geographic categories: the nonmetropolitan area and "county not reported." Relationships between STEM share and metro size are similar to those based on aggregate earnings for both 2019 and the 2005-to-2019 change.

The relationship between size and STEM intensity extends to include the U.S. nonmetropolitan area. Based on employment, the nonmetro STEM share of 2.79 percent in 2019 was considerably less than the 3.61 percent share in SC6. The change in the nonmetro share between 2005 and 2019 of 0.16 percentage points was less than the change in each of the six metro size classes. By category, the 2019 STEM share in the nonmetro area was less than in each of the metro size classes except in the science technician category. The 2005-to-2019 change in share was less than in each of the size classes in the computer and math categories.

TABLE 17
STEM AGGREGATE EARNINGS BY OCCUPATION IN METROPOLITAN AREAS BY SIZE CLASS

	STEM Total	Computer	Math	Engineer-ing	Engineer-ing Tech-nician	Science	Science Tech-nician
Aggregate Earnings, Share of Total in 2019							
United States	10.18%	5.96%	0.23%	2.52%	0.52%	0.74%	0.21%
U.S. Metropolitan Area	10.41	6.12	0.24	2.57	0.51	0.76	0.21
Employment of At Least 1 Million	11.66	7.29	0.28	2.61	0.48	0.80	0.19
Employment of 350,000 to 999,999	9.47	5.12	0.22	2.65	0.59	0.68	0.21
Employment of 200,000 to 349,999	8.37	4.11	0.15	2.62	0.54	0.73	0.22
Employment of 125,000 to 199,999	7.28	3.29	0.13	2.38	0.56	0.69	0.24
Employment of 75,000 to 124,999	6.85	3.09	0.14	2.11	0.56	0.68	0.26
Employment of Less Than 75,000	6.47	2.61	0.12	2.28	0.56	0.65	0.25
Aggregate Earnings, Percentage-Point Change in Share of Total Between 2005 and 2019							
United States	1.70	1.61	0.11	0.09	-0.18	0.09	-0.01
U.S. Metropolitan Area	1.64	1.56	0.11	0.09	-0.19	0.08	-0.01
Employment of At Least 1 Million	1.96	1.95	0.13	0.01	-0.21	0.09	-0.01
Employment of 350,000 to 999,999	1.20	1.04	0.08	0.21	-0.16	0.05	-0.02
Employment of 200,000 to 349,999	0.92	0.83	0.06	0.12	-0.18	0.09	0.00
Employment of 125,000 to 199,999	0.76	0.60	0.05	0.23	-0.16	0.05	-0.01
Employment of 75,000 to 124,999	0.63	0.45	0.06	0.19	-0.12	0.06	-0.01
Employment of Less Than 75,000	0.76	0.40	0.06	0.34	-0.09	0.06	-0.01

Sources: Emsi (employment and earnings). Definition of STEM occupations produced by authors.

TABLE 18
STEM EMPLOYMENT BY OCCUPATION IN METROPOLITAN AREAS BY SIZE CLASS

	STEM Total	Computer	Math	Engineer-ing	Engineer-ing Tech-nician	Science	Science Tech-nician
Employment, Share of Total							
United States	5.51%	3.11%	0.12%	1.22%	0.43%	0.41%	0.21%
U.S. Metropolitan Area	5.70	3.24	0.13	1.26	0.44	0.42	0.21
Employment of At Least 1 Million	6.44	3.89	0.16	1.31	0.43	0.45	0.20
Employment of 350,000 to 999,999	5.40	2.90	0.12	1.30	0.49	0.39	0.20
Employment of 200,000 to 349,999	4.63	2.28	0.08	1.22	0.44	0.40	0.21
Employment of 125,000 to 199,999	4.11	1.89	0.07	1.11	0.45	0.39	0.21
Employment of 75,000 to 124,999	3.92	1.79	0.07	0.99	0.44	0.38	0.25
Employment of Less Than 75,000	3.61	1.50	0.06	1.05	0.42	0.35	0.23
U.S. Nonmetro Area	2.79	1.02	0.04	0.84	0.36	0.32	0.21
"County Not Reported"	12.35	9.20	0.30	1.56	0.51	0.53	0.25
Employment, Percentage-Point Change in Share of Total Between 2005 and 2019							
United States	0.83	0.74	0.06	0.09	-0.12	0.06	0.00
U.S. Metropolitan Area	0.74	0.69	0.06	0.08	-0.13	0.05	0.00
Employment of At Least 1 Million	0.88	0.87	0.07	0.03	-0.15	0.06	0.00
Employment of 350,000 to 999,999	0.63	0.53	0.05	0.14	-0.12	0.04	-0.01
Employment of 200,000 to 349,999	0.47	0.41	0.03	0.08	-0.12	0.06	0.01
Employment of 125,000 to 199,999	0.36	0.28	0.03	0.12	-0.11	0.05	0.00
Employment of 75,000 to 124,999	0.33	0.20	0.03	0.12	-0.09	0.05	0.00
Employment of Less Than 75,000	0.41	0.22	0.03	0.18	-0.07	0.04	0.00
U.S. Nonmetro Area	0.16	0.10	0.02	0.10	-0.08	0.04	-0.01
"County Not Reported"	5.55	4.71	0.22	0.37	-0.08	0.23	0.10

Sources: Emsi (employment). Definition of STEM occupations produced by authors.

STEM shares in the "county not reported" category are significantly greater than the shares even in SC1. In 2019, the national "county not reported" share was 12.35 percent based on employment and 20.52 percent based on aggregate earnings. The change in share between 2005 and 2019 was 5.55 percentage points based on employment and 8.28 percentage points based on aggregate earnings. Based on employment, the "county not reported" STEM share in 2019 was greater than the share in each metro size class and in the nonmetro area in each category. The change in the "county not reported" STEM share between 2005 and 2019 was greater than in each metro size class and the nonmetro area except for the engineering technician category.

Table 19 is the counterpart to Table 17 for industries. The industrial data show the same relationship between overall STEM share and employment size in 2019 as the occupational data.

The 2005-to-2019 change in the overall STEM share of total aggregate earnings was much greater in SC1 than in the other size classes. This resulted from the services category. In contrast, the change in share in the manufacturing category was inversely related to metro area size.

Based on the 2019 STEM occupational share of employment and aggregate earnings, the nation's leading metro areas in SC1 are San Jose (with shares much higher than any other large metro area), Seattle, San Francisco, Washington D.C., Austin, Detroit, Boston, Denver,

TABLE 19
STEM AGGREGATE EARNINGS BY INDUSTRY
IN METROPOLITAN AREAS BY SIZE CLASS

	STEM Total	Manufac-turing	Services
Share of Total in 2019			
United States	9.89%	2.51%	7.38%
U.S. Metropolitan Areas	10.26	2.72	7.54
Employment of At Least 1 Million	12.31	3.05	9.26
Employment of 350,000 to 999,999	7.59	2.33	5.26
Employment of 200,000 to 349,999	7.77	2.83	4.94
Employment of 125,000 to 199,999	5.11	1.85	3.26
Employment of 75,000 to 124,999	3.88	0.98	2.90
Employment of Less Than 75,000	3.52	1.21	2.31
Percentage Point Change in Share of Total Between 2001 and 2019			
United States	1.43	-0.82	2.25
U.S. Metropolitan Areas	1.20	-0.91	2.12
Employment of At Least 1 Million	1.68	-1.01	2.69
Employment of 350,000 to 999,999	0.20	-0.88	1.08
Employment of 200,000 to 349,999	0.26	-0.87	1.13
Employment of 125,000 to 199,999	-0.15	-0.76	0.60
Employment of 75,000 to 124,999	-0.24	-0.75	0.52
Employment of Less Than 75,000	0.26	-0.26	0.52

Sources: Emsi (employment and earnings). Definition of STEM-intensive industries produced by authors.

Baltimore, and San Diego. With the exception of Washington D.C. and Austin, the same metro areas are among the leaders on the 2005-to-2019 change in share, along with Charlotte and Pittsburgh.

The San Jose, Seattle, and San Francisco metro areas stand out as ranking among the top four on all four measures. The "STEM Economic Activity by Metropolitan Area" paper, available from https://economist.asu.edu/p3-productivity-prosperity-project/knowledge-economy/, provides much more information.

Arizona's Metropolitan and Nonmetropolitan Areas

Metro Phoenix is among the 36 metro areas in the size class of employment of at least 1 million in 2019. Metro Tucson is among the 45 metro areas with employment of 350,000 to 999,999. Metro Prescott and Metro Yuma are among the 71 metro areas with employment of 75,000 to 124,999. The Flagstaff, Lake Havasu City, and Sierra Vista metro areas are among the 124 metro areas with employment of less than 75,000.

Based on occupational employment, Metro Phoenix was primarily responsible for the state's low STEM share relative to the expected share in 2019. Metro Phoenix dominates the state, accounting for 72 percent of the state's employment in 2019, and had a STEM share 0.59 percentage points lower than its size-class average. In contrast, Metro Tucson's 2019 STEM share was 0.89 percentage points greater than the average of its size class, but only 13 percent of the state's employment was located in Metro Tucson. The balance of the state had a small net negative effect on the state's actual STEM share relative to the expected share.

The somewhat lesser increase between 2005 and 2019 in Arizona's actual occupational employment STEM share versus the expected change in share primarily was due to the poor performance outside the two major metro areas, but Metro Phoenix also contributed.

The overall occupational and industrial STEM shares of aggregate earnings in 2019 are displayed for each of Arizona's seven metro areas, with comparisons to the relevant size class, in the top portion of Table 20. The change over time is shown in the bottom portion of the table. The same information is provided in Table 21 for each of the occupational categories and in Table 22 for each of the industrial categories.

While the following discussion identifies individual occupations and industries, caution is advised in evaluating these results. Except for the largest metro areas, estimates of employment and earnings for many of the individual occupations have a large margin of error in the BLS's OES program, with Emsi forced to impute the values in many cases. Similarly, many of the industrial estimates are withheld by the federal government.

In the following discussion, a "significant" occupation or industry is defined as one with an aggregate earnings share of at least 0.1 percent in 2019 in either the size class or in the metro area being discussed. "Near the top of the size class" refers to the top 10 percent of the metro areas in the size class; "near the bottom of the size class" refers to the bottom 10 percent. A significant change in aggregate earnings share over time is defined as one with a change of at least 0.05 percentage points in either the size class or in the metro area being discussed.

TABLE 20
STEM AGGREGATE EARNINGS IN ARIZONA'S METROPOLITAN AREAS

	Total Employ-ment	STEM Share Occupa-tion	STEM Share Industry	Rank Among 384 Metro Areas Occupa-tion	Rank Among 384 Metro Areas Industry	Rank in Size Class Occupa-tion	Rank in Size Class Industry
2019							
Size Class: Employment of at Least 1 Million (N=36)		11.66%	12.31%				
Phoenix-Mesa-Chandler	2,342,875	10.34	10.18	65	50	21	14
Size Class: Employment of 350,000 to 999,999 (N=45)		9.47	7.59				
Tucson	433,481	11.57	14.69	47	21	8	3
Size Class: Employment of 75,000 to 124,999 (N=71)		6.85	3.88				
Prescott Valley Prescott	77,881	4.07	2.97	344	244	63	38
Yuma	80,858	5.27	3.77	263	197	51	27
Size Class: Employment of Less Than 75,000 (N=124)		6.47	3.52				
Flagstaff	70,649	5.59	1.19	248	362	54	102
Lake Havasu City-Kingman	58,619	2.92	1.39	380	347	122	92
Sierra Vista-Douglas	43,202	12.21	7.47	37	81	4	10
Change Between 2001/2005 and 2019*							
Size Class: Employment of at Least 1 Million (N=36)		1.96	1.68				
Phoenix-Mesa-Chandler		1.56	-1.33	78	325	21	33
Size Class: Employment of 350,000 to 999,999 (N=45)		1.20	0.20				
Tucson		1.13	-0.61	125	297	19	33
Size Class: Employment of 75,000 to 124,999 (N=71)		0.63	-0.24				
Prescott Valley Prescott		0.15	-0.03	272	228	48	45
Yuma		0.89	1.20	152	88	24	14
Size Class: Employment of Less Than 100,000 (N=124)		0.76	0.26				
Flagstaff		-0.57	0.03	362	217	116	70
Lake Havasu City-Kingman		-0.20	-0.80	328	310	99	103
Sierra Vista-Douglas		1.13	1.44	126	76	29	24

* Between 2005 and 2019 for occupations and between 2001 and 2019 for industries; measured as the percentage point change.

Sources: Emsi (employment and earnings). Definition of STEM occupations and STEM-intensive industries produced by authors.

TABLE 21
STEM AGGREGATE EARNINGS BY OCCUPATIONAL CATEGORY IN ARIZONA'S METROPOLITAN AREAS

	Computer			Math		
	Share	Rank*	Rank**	Share	Rank*	Rank**
2019						
Size Class: Employment of at Least 1 Million (N=36)	7.29%			0.28%		
Phoenix-Mesa-Chandler	6.61	36	16	0.29	36	13
Size Class: Employment of 350,000 to 999,999 (N=45)	5.12			0.22		
Tucson	6.03	43	10	0.12	187	34
Size Class: Employment of 75,000 to 124,999 (N=71)	3.09			0.14		
Prescott Valley Prescott	1.64	338	63	0.03	358	66
Yuma	2.28	249	47	0.15	147	25
Size Class: Employment of Less Than 75,000 (N=124)	2.61			0.12		
Flagstaff	2.06	282	68	0.04	332	83
Lake Havasu City-Kingman	1.12	382	124	0.03	360	105
Sierra Vista-Douglas	7.59	24	2	0.20	88	15
Change Between 2005 and 2019^						
Size Class: Employment of at Least 1 Million (N=36)	1.95			0.13		
Phoenix-Mesa-Chandler	2.18	21	9	0.18	24	8
Size Class: Employment of 350,000 to 999,999 (N=45)	1.04			0.08		
Tucson	1.26	70	14	0.07	131	19
Size Class: Employment of 75,000 to 124,999 (N=71)	0.45			0.06		
Prescott Valley Prescott	0.47	189	29	0.02	303	60
Yuma	0.24	262	44	0.06	146	25
Size Class: Employment of Less Than 75,000 (N=124)	0.40			0.06		
Flagstaff	0.04	320	92	0.00	344	98
Lake Havasu City-Kingman	-0.12	350	106	0.02	270	58
Sierra Vista-Douglas	0.98	99	14	0.07	132	34

(continued)

TABLE 21 (continued)
STEM AGGREGATE EARNINGS BY OCCUPATIONAL CATEGORY IN ARIZONA'S METROPOLITAN AREAS

	Engineering			Engineering Technician		
	Share	Rank*	Rank**	Share	Rank*	Rank**
2019						
Size Class: Employment of at Least 1 Million (N=36)	2.61%			0.48%		
Phoenix-Mesa-Chandler	2.32	141	22	0.71	67	5
Size Class: Employment of 350,000 to 999,999 (N=45)	2.65			0.59		
Tucson	3.76	45	5	0.60	111	17
Size Class: Employment of 75,000 to 124,999 (N=71)	2.11			0.56		
Prescott Valley Prescott	1.62	251	39	0.33	317	60
Yuma	1.54	257	40	0.57	138	25
Size Class: Employment of Less Than 75,000 (N=124)	2.28			0.56		
Flagstaff	1.49	269	78	0.30	347	103
Lake Havasu City-Kingman	1.33	301	93	0.22	367	112
Sierra Vista-Douglas	2.91	85	18	0.69	78	24
Change Between 2005 and 2019^						
Size Class: Employment of at Least 1 Million (N=36)	0.01			-0.21		
Phoenix-Mesa-Chandler	-0.40	353	34	-0.39	371	35
Size Class: Employment of 350,000 to 999,999 (N=45)	0.21			-0.16		
Tucson	0.03	240	35	-0.33	355	40
Size Class: Employment of 75,000 to 124,999 (N=71)	0.19			-0.12		
Prescott Valley Prescott	-0.03	267	49	-0.26	322	62
Yuma	0.37	97	20	0.10	10	3
Size Class: Employment of Less Than 75,000 (N=124)	0.34			-0.09		
Flagstaff	-0.17	315	100	-0.11	162	74
Lake Havasu City-Kingman	-0.01	260	84	-0.10	140	63
Sierra Vista-Douglas	-0.09	287	90	-0.01	46	24

(continued)

TABLE 21 (continued)
STEM AGGREGATE EARNINGS BY OCCUPATIONAL CATEGORY IN ARIZONA'S METROPOLITAN AREAS

	Science			Science Technician		
	Share	Rank*	Rank**	Share	Rank*	Rank**
2019						
Size Class: Employment of at Least 1 Million (N=36)	0.80%			0.19%		
Phoenix-Mesa-Chandler	0.27	345	36	0.14	284	32
Size Class: Employment of 350,000 to 999,999 (N=45)	0.68			0.21		
Tucson	0.90	76	9	0.17	230	31
Size Class: Employment of 75,000 to 124,999 (N=71)	0.68			0.26		
Prescott Valley Prescott	0.32	313	54	0.13	301	58
Yuma	0.45	235	43	0.29	86	18
Size Class: Employment of Less Than 75,000 (N=124)	0.65			0.25		
Flagstaff	0.93	71	23	0.78	9	6
Lake Havasu City-Kingman	0.15	376	116	0.07	372	116
Sierra Vista-Douglas	0.36	288	86	0.46	33	18
Change Between 2005 and 2019^						
Size Class: Employment of at Least 1 Million (N=36)	0.09			-0.01		
Phoenix-Mesa-Chandler	0.00	242	25	0.00	168	14
Size Class: Employment of 350,000 to 999,999 (N=45)	0.05			-0.02		
Tucson	0.16	66	5	-0.05	299	36
Size Class: Employment of 75,000 to 124,999 (N=71)	0.06			-0.01		
Prescott Valley Prescott	0.01	232	43	-0.05	301	53
Yuma	0.06	154	29	0.07	37	9
Size Class: Employment of Less Than 75,000 (N=124)	0.06			-0.01		
Flagstaff	0.00	239	75	-0.34	383	123
Lake Havasu City-Kingman	0.03	195	63	-0.02	242	77
Sierra Vista-Douglas	0.14	80	32	0.04	62	31

* Among the nation's 384 metro areas. ** In the size class. ^ Measured as the percentage point change.

Sources: Emsi (employment and earnings). Definition of STEM occupations produced by authors.

TABLE 22
STEM AGGREGATE EARNINGS BY INDUSTRIAL CATEGORY IN ARIZONA'S METROPOLITAN AREAS

	Manufacturing			Services		
	Share	**Rank***	**Rank****	**Share**	**Rank***	**Rank****
2019						
Size Class: Employment of at Least 1 Million (N=36)	3.05%			9.26%		
Phoenix-Mesa-Chandler	4.59	37	7	5.59	65	23
Size Class: Employment of 350,000 to 999,999 (N=45)	2.33			5.26		
Tucson	9.94	9	2	4.75	89	18
Size Class: Employment of 75,000 to 124,999 (N=71)	0.98			2.90		
Prescott Valley Prescott	1.18	151	22	1.79	266	48
Yuma	0.10	343	60	3.67	132	16
Size Class: Employment of Less Than 75,000 (N=124)	1.21			2.31		
Flagstaff	0.11	335	87	1.07	339	87
Lake Havasu City-Kingman	0.57	220	48	0.82	367	107
Sierra Vista-Douglas	0.10	339	91	7.36	38	2
Change Between 2001 and 2019^						
Size Class: Employment of at Least 1 Million (N=36)	-1.01			2.69		
Phoenix-Mesa-Chandler	-2.97	362	32	1.64	65	14
Size Class: Employment of 350,000 to 999,999 (N=45)	-0.88			1.08		
Tucson	-1.27	316	36	0.66	166	22
Size Class: Employment of 75,000 to 124,999 (N=71)	-0.75			0.52		
Prescott Valley Prescott	-0.13	181	40	0.10	278	51
Yuma	-0.65	270	55	1.85	53	7
Size Class: Employment of Less Than 75,000 (N=124)	-0.26			0.52		
Flagstaff	-0.18	192	78	0.21	259	66
Lake Havasu City-Kingman	0.18	79	31	-0.98	375	120
Sierra Vista-Douglas	-0.32	223	89	1.76	60	12

* Among the nation's 384 metro areas. ** In the size class. ^ Measured as the percentage point change.

Sources: Emsi (employment and earnings). Definition of STEM-intensive industries produced by authors.

Metro Phoenix
In 2019, the STEM share of occupational aggregate earnings of 10.34 percent in Metro Phoenix was slightly above the national average but below the 11.66 percent average share of its size class, ranking 21st of the 36 metro areas with employment of at least 1 million. The subpar overall ranking can be traced to three of the six occupational categories: science (last in the size class), science technician (rank of 32nd), and engineering (22nd). In contrast, Metro Phoenix ranked fifth in the size class in the engineering technician category. Metro Phoenix also ranked in the top half of its size class in the computer and math categories, but its share was similar to the size-class average in the math category and lower than the size-class average in the computer category.

Among the significant occupations, Metro Phoenix ranked near the top of its size class on the share of aggregate earnings in 2019 only in the "architectural and civil drafters" occupation. It did not rank near the bottom of its size class in any significant occupation.

The change in the STEM share of occupational aggregate earnings between 2005 and 2019 in Metro Phoenix of 1.56 percentage points was less than both the national average and the size class average of 1.96 percentage points. Metro Phoenix ranked 21st among the 36 largest metro areas, underperforming its size class in three categories: engineering (third lowest), engineering technician (second lowest), and science (rank of 25th). In contrast, Metro Phoenix ranked ninth in the size class on the change in share in the computer category and eighth in math.

Among the significant occupations, Metro Phoenix ranked near the top of its size class in the 2005-to-2019 change in share of aggregate earnings in the "computer programmers" occupation. It ranked near the bottom of the size class in the change in share in the "aerospace engineers," "civil engineers," "computer hardware engineers," and "civil engineering technologists and technicians" occupations.

In 2019, the STEM share of industrial aggregate earnings in Metro Phoenix of 10.18 percent was slightly above the national average but well below the average share in its size class of 12.31 percent, though it ranked 14th of the 36 metro areas. In the manufacturing category, Metro Phoenix ranked seventh in the size class and in the top 10 percent nationally. However, Metro Phoenix ranked 23rd in the services category with a share considerably below that of the size class.

Among the significant industries, Metro Phoenix ranked near the top of its size class on the share of aggregate earnings in 2019 in four: "semiconductor and related device manufacturing" (ninth in the nation), "search, detection, navigation, guidance, aeronautical, and nautical system and instrument manufacturing," "aircraft engine and engine parts manufacturing," and "satellite telecommunications" (second in the nation). Metro Phoenix did not rank near the bottom of the size class in any significant industry.

The change in the STEM share of industrial aggregate earnings between 2001 and 2019 in Metro Phoenix of -1.33 percentage points was far below both the national average and the size class average of 1.68 percentage points. Metro Phoenix ranked 33rd among the 36 largest metro areas, underperforming its size class in both categories, but particularly in manufacturing (fifth lowest).

Despite its lesser gain in services than the size class average, Metro Phoenix ranked 14th in the size class.

Metro Phoenix ranked near the top of its size class in the 2001-to-2019 change in share of aggregate earnings in two significant industries: “satellite communications” (first in size class and second in nation) and “other computer related services.” It ranked near the bottom of the size class in six manufacturing industries: “semiconductor and related device manufacturing” (in the bottom 10 nationally), “electronic connector manufacturing,” “search, detection, navigation, guidance, aeronautical, and nautical system and instrument manufacturing,” “automatic environmental control manufacturing for residential, commercial, and appliance use” (in the bottom 10 nationally), “totalizing fluid meter and counting device manufacturing,” and “aircraft engine and engine parts manufacturing.”

Median earnings per occupational STEM job adjusted for the cost of living was $86,014 in 2019, ranking 25th in the size class. The adjusted change between 2005 and 2019 ranked fourth, based on both the dollar change and the percent change (16.2 percent).

Occupational STEM job quality in Metro Phoenix in 2019 was below the national average and the median of the 36 metro areas in its size class, ranking 26th in the size class. The change in occupational job quality between 2005 and 2019 was a little stronger in Metro Phoenix than the national average and about equal to the median of the size class, ranking 18th.

In contrast, industrial STEM job quality in Metro Phoenix in 2019 was considerably better than the national average and the size-class median, ranking ninth in the size class. The change in industrial job quality between 2001 and 2019 in Metro Phoenix was a little less than the national average but was better than the median of the size class, ranking 15th.

After removing the effect of job quality, the balance of median earnings per occupational STEM job adjusted for the cost of living ranked 23rd in the size class in 2019 and the dollar change between 2005 and 2019 ranked fourth.

Metro Tucson

In 2019, the STEM share of occupational aggregate earnings of 11.57 percent in Metro Tucson was above the national average and considerably greater than the 9.47 percent average share in its size class, ranking eighth of the 45 metro areas with employment between 350,000 and 999,999. The strong overall rank can be traced to four of the six occupational categories: engineering (fifth in the size class), science (ninth), computer (10th), and engineering technician (17th). Metro Tucson ranked below the middle of the size class in the math (34th) and science technician (31st) categories.

Among the significant occupations, Metro Tucson ranked near the top of its size class on the share of aggregate earnings in 2019 in four: “natural sciences managers,” “computer user support specialists,” “electrical engineers,” and “mechanical engineers.” It did not rank near the bottom of its size class in any significant occupation.

The change in the STEM share of occupational aggregate earnings between 2005 and 2019 in Metro Tucson of 1.13 percentage points was less than the national average and slightly below the size class average of 1.20 percentage points. Metro Tucson ranked 19th among the 45 metro areas in the size class. It underperformed its size class in three categories: engineering (rank of 35th), engineering technician (40th), and science technician (36th). In contrast, Metro Tucson ranked fifth in the size class in the science category, 14th in the computer category, and 19th in math.

Among the significant occupations, Metro Tucson ranked near the top of its size class in the 2005-to-2019 change in share of aggregate earnings in three: "electronics engineers, except computer," "engineers, all other," and "astronomers." In contrast, Metro Tucson ranked near the bottom of its size class in the "architectural and engineering managers" and "aerospace engineers" occupations.

In 2019, the STEM share of industrial aggregate earnings in Metro Tucson of 14.69 percent was considerably above the national average (rank of 21st) and its size-class average of 7.59 percent (rank of third of the 45 metro areas). In the manufacturing category, Metro Tucson ranked ninth nationally and second in the size class. In the services category, Metro Tucson ranked 18th in the size class, but with a share below the size-class average.

Among the significant industries, Metro Tucson ranked near the top of its size class on the share of aggregate earnings in 2019 in five. More than half of the industrial STEM activity in Metro Tucson was in one industry — "guided missile and space vehicle manufacturing" — in which Metro Tucson ranked first in the nation. This industry's share of 7.66 percent compared to the median of its size class of zero. Other leading industries were "totalizing fluid meter and counting device manufacturing" (first in the size class and sixth nationally), "analytical laboratory instrument manufacturing" (second in the size class and fifth nationally), "software publishers," and "research and development in nanotechnology." Metro Tucson did not rank near the bottom of its size class in any significant industry.

The change in the STEM share of industrial aggregate earnings between 2001 and 2019 in Metro Tucson of -0.61 percentage points was below both the national average and the size-class average of 0.20 percentage points. Metro Tucson ranked 33rd among the 45 metro areas in its size class, underperforming its size class in both categories, ranking 36th in manufacturing and 22nd in services.

Considerable changes occurred between 2001 and 2019 in the share of aggregate earnings in numerous industries in Metro Tucson. Among the significant industries, Metro Tucson ranked near the top of its size class on the change in share in six: "search, detection, navigation, guidance, aeronautical, and nautical system and instrument manufacturing," "instruments and related products manufacturing for measuring, displaying and controlling industrial process variables," "analytical laboratory instrument manufacturing" (largest in the size class and second in the nation), "guided missile and space vehicle manufacturing" (largest in the nation), "wireless telecommunications carriers (except satellite)," and "research and development in nanotechnology (ninth in the nation)."

However, Metro Tucson had among the largest losses of share in its size class in 11 significant industries: “semiconductor machinery manufacturing,” “electronic computer manufacturing” (bottom 10 in the nation), “computer storage device manufacturing,” “bare printed circuit board manufacturing,” “electromedical and electrotherapeutic apparatus manufacturing,” “automatic environmental control manufacturing for residential, commercial, and appliance use,” “aircraft manufacturing” (bottom 10 in the nation), “other aircraft parts and auxiliary equipment manufacturing,” “software publishers,” “engineering services,” and “research and development in the physical, engineering, and life sciences (except nanotechnology and biotechnology).”

Median earnings per occupational STEM job adjusted for the cost of living was $88,190 in 2019, ranking 18th in the size class. The adjusted dollar change between 2005 and 2019 ranked 21st, while the percent change (10.5 percent) ranked 20th.

Occupational STEM job quality in Metro Tucson in 2019 was below the national average but was better than the median of the 45 metro areas in its size class, ranking 16th. The change in occupational job quality between 2005 and 2019 in Metro Tucson was worse than the national average but a bit better than the median of the size class, ranking 19th.

In contrast, industrial STEM job quality in Metro Tucson in 2019 was far better than the national average and the size-class median, ranking fourth in the size class. The change in industrial job quality between 2001 and 2019 in Metro Tucson was worse than the national average but better than the median of the size class, ranking 16th.

After removing the effect of job quality, the balance of median earnings per occupational STEM job adjusted for the cost of living ranked 18th in the size class in 2019 and the dollar change between 2005 and 2019 ranked 21st.

Metro Flagstaff

In 2019, the STEM share of occupational aggregate earnings of 5.59 percent in Metro Flagstaff was considerably below the national average and below the 6.47 percent average share in its size class, though at 54th Metro Flagstaff ranked above the middle of the 124 metro areas with employment of less than 75,000. Its share was less than the size-class average and its rank was below the middle of the size class in four of the six categories: computer (rank of 68th), math (83rd), engineering (78th), and engineering technician (103rd). In contrast, Metro Flagstaff compared favorably in its size class in science (23rd) and science technician (sixth, and ninth highest in the nation).

Among the significant occupations, Metro Flagstaff ranked near the top of its size class on the share of aggregate earnings in 2019 in four: “electronics engineers, except computer,” “zoologists and wildlife biologists,” “environmental science and protection technicians, including health” (fourth nationally), and “forest and conservation technicians” (first nationally). In contrast, Metro Flagstaff ranked near the bottom of its size class in the “industrial engineers” occupation.

The change in the STEM share of occupational aggregate earnings between 2005 and 2019 in Metro Flagstaff of -0.57 percentage points was considerably less than both the national average and the size-class average of 0.76 percentage points. Metro Flagstaff ranked 116th among the 124 metro areas in the size class and in the bottom 25 nationally, underperforming its size class in each of the six categories, including second worst in the nation in the science technician category.

Metro Flagstaff ranked near the top of its size class on the change in share of aggregate earnings between 2005 and 2019 in the "bioengineers and biomedical engineers" occupation. However, it had the largest loss in share in the size class in the "environmental science and protection technicians, including health" and "forest and conservation technicians" occupations.

In 2019, the STEM share of industrial aggregate earnings in Metro Flagstaff of 1.19 percent was far below the national average and the size-class average of 3.52 percent, ranking in the bottom 25 nationally and 102nd in the size class. Metro Flagstaff compared poorly in both the manufacturing category (87th in the size class) and the services category (also 87th).

Among the significant industries, Metro Flagstaff ranked near the top of its size class on the share of aggregate earnings in 2019 in "environmental consulting services." It did not rank near the bottom of its size class in any significant industry.

The change in the STEM share of industrial aggregate earnings between 2001 and 2019 in Metro Flagstaff of 0.03 percentage points was below both the national average and the size-class average of 0.26 percentage points. Metro Flagstaff ranked 70th among the 124 metro areas in its size class, ranking 78th in manufacturing and 66th in services.

Metro Flagstaff ranked near the top of its size class on the 2001-to-2019 change in share of aggregate earnings in the "electronic connector manufacturing" and "environmental consulting services" industries. It ranked near the bottom in "pharmaceutical preparation manufacturing," "semiconductor and related device manufacturing," and "research and development in other physical, engineering, and life sciences" industries.

Median earnings per occupational STEM job adjusted for the cost of living was only $66,039 in 2019, ranking 122nd in the size class. The adjusted dollar change between 2005 and 2019 ranked 62nd, while the percent change (8.7 percent) ranked 51st.

Occupational STEM job quality in Metro Flagstaff in 2019 was far below the national average and much below the size-class median, ranking 120th of the 124 metro areas in the size class. However, the change in occupational job quality between 2005 and 2019 in Metro Flagstaff was stronger than the national average and size-class median, ranking 17th in its size class.

Industrial STEM job quality in Metro Flagstaff in 2019 was far below the national average, and less than the size-class median, ranking 83rd. The change in industrial job quality between 2001 and 2019 in Metro Flagstaff was worse than the national average and the median of the size class, ranking 89th.

After removing the effect of job quality, the balance of median earnings per occupational STEM job adjusted for the cost of living ranked only 118th in the size class in 2019 and the dollar change between 2005 and 2019 ranked 63rd.

Metro Lake Havasu City

In 2019, the STEM share of occupational aggregate earnings of 2.92 percent in Metro Lake Havasu City was far below the national average and the 6.47 percent average share in its size class, ranking fifth lowest among all 384 metro areas. The share was less than the size-class average and the rank was well below the middle of the size class in each of the six categories. It ranked in the bottom 25 in the nation in the computer, math, engineering technician, science, and science technician categories.

Among the significant occupations, Metro Lake Havasu City ranked near the top of its size class on the share of aggregate earnings in 2019 in "electronics engineers, except computer." It ranked near the bottom of the size class in "computer and information systems managers" and "network and computer systems administrators," each of which was in the bottom 10 nationally.

The change in the STEM share of occupational aggregate earnings between 2005 and 2019 in Metro Lake Havasu City of -0.20 percentage points was considerably less than the national average and the size-class average of 0.76 percentage points. Metro Lake Havasu City ranked 99th among the 124 metro areas in the size class, underperforming its size class in each category, though ranking just above the middle in math. It compared particularly poorly in the computer category, ranking 106th in the size class and 350th nationally.

Among the significant occupations, Metro Lake Havasu City ranked near the top of its size class on the 2005-to-2019 change in share of aggregate earnings in the "electronics engineers, except computer" occupation, ranking in the top 10 nationally. It ranked near the bottom of the size class in the "computer user support specialists" and "civil engineers" occupations.

In 2019, the STEM share of industrial aggregate earnings in Metro Lake Havasu City of 1.39 percent was far below the national average and the size-class average of 3.52 percent, ranking 92nd of 124 metro areas. Metro Lake Havasu City's share was below the size-class average in both categories, but its manufacturing rank was 48th. It ranked 107th in services.

Metro Lake Havasu City ranked near the top of its size class in two significant industries in 2019: "printed circuit assembly (electronic assembly) manufacturing" and "aircraft engine and engine parts manufacturing." It ranked near the bottom of its size class in the "computer systems design services" industry.

The change in the STEM share of industrial aggregate earnings between 2001 and 2019 in Metro Lake Havasu City of -0.80 percentage points was below both the national average and the size-class average of 0.26 percentage points. Metro Lake Havasu City ranked 103rd among the 124 metro areas in its size class. It outperformed the nation and size class in the manufacturing category, ranking 31st in its size class. However, it ranked 120th in the size class, and 375th nationally, in the services category.

Metro Lake Havasu City ranked near the top of its size class on the change in share of aggregate earnings between 2001 and 2019 in the "audio and video equipment manufacturing" and "printed circuit assembly (electronic assembly) manufacturing" industries. It ranked last in the size class in the "testing laboratories" industry, but this may be due to a geographical assignment error — the change in Metro Yuma ranked first in this industry.

Median earnings per occupational STEM job adjusted for the cost of living was $77,456 in 2019, ranking 95th in the size class. The adjusted change between 2005 and 2019 ranked 87th, based on both the dollar change and the percent change (3.1 percent).

Occupational STEM job quality in Metro Lake Havasu City in 2019 was considerably below the national average, but was marginally better than the size-class median, ranking 57th of the 124 metro areas in its size class. The change in occupational job quality between 2005 and 2019 in Metro Lake Havasu City was below the U.S. average but somewhat better than the size-class median, ranking 46th.

Industrial STEM job quality in Metro Lake Havasu City in 2019 was far below the national average and the size-class median, ranking 116th in the size class. The change in industrial job quality between 2001 and 2019 in Metro Lake Havasu City was considerably below the U.S. average and the size-class median, ranking 104th.

After removing the effect of job quality, the balance of median earnings per occupational STEM job adjusted for the cost of living ranked 103rd in the size class in 2019 and the dollar change between 2005 and 2019 ranked 87th.

Metro Prescott

In 2019, the STEM share of occupational aggregate earnings of 4.07 percent in Metro Prescott was far below the national average and the 6.85 percent average share in its size class, ranking 63rd of the 71 metro areas with employment of 75,000 to 124,999. The share was less than the that of the size-class average and the rank was well below the middle of the size class in each of the six categories.

Among the significant occupations, Metro Prescott ranked near the top of its size class on the share of aggregate earnings in 2019 in "electrical engineers" and "health and safety engineers, except mining safety engineers and inspectors." It ranked near the bottom of its size class in the "computer and information systems managers," "computer systems analysts" (among the bottom 10 nationally), and "mechanical engineers" occupations.

The change in the STEM share of occupational aggregate earnings between 2005 and 2019 in Metro Prescott of 0.15 percentage points was less than both the national average and the size-class average of 0.63 percentage points. Metro Prescott ranked 48th among the 71 metro areas in the size class, underperforming its size class in each category except computer.

Among the significant occupations, Metro Prescott ranked near the top of its size class on the 2005-to-2019 change in share of aggregate earnings in the "electrical engineers" and "mining and geological engineers, including mining safety engineers" occupations. However, it ranked near the bottom in the “civil engineers,” “health and safety engineers, except mining safety engineers and inspectors,” and “architectural and civil drafters” occupations.

In 2019, the STEM share of industrial aggregate earnings in Metro Prescott of 2.97 percent was considerably below the national average and below the size-class average of 3.88 percent, ranking 38th. It ranked 22nd in the manufacturing category and 48th in the services category.

Metro Prescott ranked near the top of its size class on the share of aggregate earnings in 2019 in four significant industries: “semiconductor machinery manufacturing” (eighth in the nation), “search, detection, navigation, guidance, aeronautical, and nautical system and instrument manufacturing,” “analytical laboratory instrument manufacturing,” and “other aircraft parts and auxiliary equipment manufacturing.” It did not rank near the bottom of the size class in any significant industry.

The change in the STEM share of industrial aggregate earnings between 2001 and 2019 in Metro Prescott of -0.03 percentage points was below the national average but a little better than the size-class average of -0.24 percentage points. Metro Prescott ranked 45th among the 71 metro areas in its size class, with ranks of 40th in the manufacturing category and 51st in the services category.

Metro Prescott ranked near the top of its size class on the change in share of aggregate earnings in three significant industries: “semiconductor machinery manufacturing” (fifth in the nation), “other communications equipment manufacturing,” and “analytical laboratory instrument manufacturing.” However, Metro Prescott had among the largest losses in the “semiconductor and related device manufacturing,” “other aircraft parts and auxiliary equipment manufacturing,” “surveying and mapping (except geophysical) services,” and “other scientific and technical consulting services” industries.

Median earnings per occupational STEM job adjusted for the cost of living was only $69,145 in 2019, ranking 66th in the size class. The adjusted dollar change between 2005 and 2019 ranked 35th, while the percent change (9.6 percent) ranked 31st.

Occupational STEM job quality in Metro Prescott in 2019 was far below the national average and below the median of its size class, ranking 65th of the 71 metro areas. The change in occupational job quality between 2005 and 2019 in Metro Prescott also was below the U.S. average and the size-class median, ranking 53rd.

Industrial STEM job quality in Metro Prescott in 2019 was far below the national average, but was better than the size-class median, ranking 28th. The change in industrial job quality between 2001 and 2019 in Metro Prescott exceeded the national average and size-class median, ranking 19th.

After removing the effect of job quality, the balance of median earnings per occupational STEM job adjusted for the cost of living ranked only 63rd in the size class in 2019 and the dollar change between 2005 and 2019 ranked 34th.

Metro Sierra Vista

In 2019, the STEM share of occupational aggregate earnings of 12.21 percent in Metro Sierra Vista was above the national average and considerably greater than the average share of 6.47 percent in its size class, ranking fourth of the 124 metro areas with employment of less than 75,000 and among the top 10 percent of all 384 metro areas. The strong overall rank can be traced to five of the six categories: computer (rank of second in the size class), math (15th), engineering (18th), engineering technician (24th), and science technician (18th).

Among the significant occupations, Metro Sierra Vista ranked near the top of its size class in 2019 in 15 occupations — eight in the computer category and seven spread across the other five categories — "computer systems analysts," "information security analysts" (tenth nationally), "computer network architects," "network and computer systems administrators," "database administrators and database architects," "software developers and software quality assurance analysts and testers," "Web developers and Web and digital interface designers" (first in size class and third in nation), "computer occupations, all other" (first in nation), "operations research analysts," "computer hardware engineers" (second in size class and seventh in nation), "electronics engineers, except computer," "civil engineering technologists and technicians," "environmental scientists and specialists, including health," "biological technicians" (seventh nationally), and "geological and hydrologic technicians." Metro Sierra Vista ranked near the bottom of its size class and in the bottom 10 nationally in the "mechanical engineers" occupation.

The change in the STEM share of occupational aggregate earnings between 2005 and 2019 in Metro Sierra Vista of 1.13 percentage points was less than the national average but greater than the size-class average of 0.76 percentage points. Metro Sierra Vista ranked 29th among the 124 metro areas in the size class, outperforming its size class in each category except engineering, in which it ranked 90th.

In Metro Sierra Vista among the significant occupations, nine ranked near the top of its size class on the 2005-to-2019 change in share of aggregate earnings, but seven occupations ranked near the bottom. The highly ranked occupations were "information security analysts," "computer network architects," "database administrators and database architects," "Web developers and Web and digital interface designers" (first in the size class and second in the nation), "computer occupations, all other" (first in the nation), "electronics engineers, except computer," "civil engineering technologists and technicians," "environmental scientists and specialists, including health" (first in the nation), and "geological and hydrologic technicians" (fifth in the nation). The low-ranking occupations were "computer systems analysts," "computer user support specialists" (bottom 10 in the nation), "computer programmers," "software developers and software quality assurance analysts and testers," "computer hardware engineers," "mechanical engineers," and "life, physical, and social science technicians, all other."

In 2019, the STEM share of industrial aggregate earnings in Metro Sierra Vista of 7.47 percent was below the national average but considerably above the size-class average of 3.52 percent (rank of 10th). Metro Sierra Vista ranked second in the size class in the services category (and in the top 10 percent nationally) but only 91st in the manufacturing category.

Metro Sierra Vista ranked near the top of its size class on the share of aggregate earnings in 2019 in five significant industries: “engineering services,” “custom computer programming services,” “computer systems design services,” “computer facilities management services” (second in the size class and fourth in the nation), and “research and development in nanotechnology” (first in the size class and ninth in the nation). Metro Sierra Vista did not rank near the bottom of its size class in any significant industry.

The change in the STEM share of industrial aggregate earnings between 2001 and 2019 in Metro Sierra Vista of 1.44 percentage points equaled the national average and was well above the size-class average of 0.26 percentage points. Metro Sierra Vista ranked 24th among the 124 metro areas in its size class. It ranked 12th in the services category but only 89th in the manufacturing category.

Metro Sierra Vista ranked near the top of its size class on the change in share of aggregate earnings between 2001 and 2019 in four significant services industries: “other electronic component manufacturing,” “engineering services,” “computer facilities management services” (first in the nation), and “research and development in nanotechnology (first in the size class and eighth in the nation). However, Metro Sierra Vista had among the largest losses in the size class in two significant industries: “software and other prerecorded compact disc, tape, and record reproducing” and “computer systems design services.”

Median earnings per occupational STEM job adjusted for the cost of living was $106,149 in 2019, ranking second in the size class. The adjusted dollar change between 2005 and 2019 ranked first, while the percent change (25.4 percent) ranked second.

Occupational STEM job quality in Metro Sierra Vista in 2019 was below the national average, but considerably above the size-class median, ranking ninth among the 124 metro areas in its size class. The change in occupational job quality between 2005 and 2019 in Metro Sierra Vista was worse than the national average but equal to the size-class median, ranking 63rd.

Industrial STEM job quality in Metro Sierra Vista in 2019 was far below the national average but above the size-class median, ranking 51st in the size class. The change in industrial job quality between 2001 and 2019 in Metro Sierra Vista was far below the national average and size-class median, ranking 108th.

After removing the effect of job quality, the balance of median earnings per occupational STEM job adjusted for the cost of living ranked third in the size class in 2019 and the dollar change between 2005 and 2019 ranked first.

Metro Yuma
In 2019, the STEM share of occupational aggregate earnings of 5.27 percent in Metro Yuma was considerably below the national average and below the average share of 6.47 percent in its size class, ranking 51st of the 71 metro areas with employment of between 75,000 and 124,999. In three of the six categories, the share was less than the size-class average and the rank was below the middle of the size class: computer (47th in the size class), engineering (40th), and science (43rd).

Among the significant occupations, Metro Yuma ranked near the top of the size class in the share of aggregate earnings in 2019 in three: “information security analysts,” “electrical and electronic engineering technologists and technicians” (ninth nationally), and ”biological scientists, all other.” Metro Yuma ranked near the bottom of its size class and in the bottom 10 nationally in the “architectural and engineering managers” occupation.

The change in the STEM share of occupational aggregate earnings between 2005 and 2019 in Metro Yuma of 0.89 percentage points was less than the national average but a little more than the size-class average of 0.63 percentage points. Metro Yuma ranked 24th among the 71 metro areas in the size class. It outperformed its size class in the engineering, engineering technician, and science technician categories, but underperformed in the computer category.

Among the significant occupations, Metro Yuma ranked near the top of its size class on the change in share of aggregate earnings between 2005 and 2019 in five: “information security analysts,” “computer occupations, all other,” “engineers, all other,” “electrical and electronic engineering technologists and technicians” (third in nation), and “biological scientists, all other.” However, it was near the bottom of the size class in the “computer systems analysts” occupation.

In 2019, the STEM share of industrial aggregate earnings in Metro Yuma of 3.77 percent was considerably below the national average and marginally below the size-class average of 3.88 percent, ranking 51st. Metro Yuma ranked 16th in the services category but only 60th in the manufacturing category.

Metro Yuma ranked near the top of its size class on the share of aggregate earnings in 2019 in two significant industries: “testing laboratories” (first in size class and third in nation) and “custom computer programming services.” It did not rank near the bottom of the size class in any of the significant industries.

The change in the STEM share of industrial aggregate earnings between 2001 and 2019 in Metro Yuma of 1.20 percentage points was a little less than the national average but better than the size-class average of -0.24 percentage points. Metro Yuma ranked 14th among the 71 metro areas in its size class, with a rank of 12th in the services category. However, it ranked 89th in the manufacturing category.

Metro Yuma ranked near the top of its size class on the change in share of aggregate earnings between 2001 and 2019 in three significant industries: “testing laboratories” (largest gain in the nation), “custom computer programming services,” and “research and development in nanotechnology.” However, Metro Yuma had among the largest losses in the size class in three significant industries: “aircraft manufacturing,” “all other telecommunications,” and “data processing, hosting, and related services.”

Median earnings per occupational STEM job adjusted for the cost of living was $80,427 in 2019, ranking 34th in the size class. The adjusted dollar change between 2005 and 2019 ranked 11th, while the percent change (16.3 percent) ranked 10th.

Occupational STEM job quality in Metro Yuma in 2019 was far below the national average and considerably worse than its size-class median, ranking 66th among the 71 metro areas. The change in occupational job quality between 2005 and 2019 in Metro Yuma also was worse than the national average and size-class median, ranking 68th.

Industrial STEM job quality in Metro Yuma in 2019 also was far below the national average and the size-class median, ranking 67th in its size class. The change in industrial job quality between 2001 and 2019 in Metro Yuma also was far below the national average and the size-class median, ranking 62nd in its size class.

After removing the effect of job quality, the balance of median earnings per occupational STEM job adjusted for the cost of living ranked 11th in the size class in 2019 and the dollar change between 2005 and 2019 ranked 10th.

Nonmetropolitan Arizona

Arizona's nonmetro area — the sum of Apache, Gila, Graham, Greenlee, La Paz, Navajo, and Santa Cruz counties — is compared to the state's seven metro areas on the STEM share of aggregate earnings in 2019 in the top part of Table 23, not considering the relationship between area size and STEM intensity. The overall STEM occupational share in nonmetro Arizona in 2019 ranked sixth among the eight substate areas, roughly similar to the shares in four of the five less-populous metro areas. However, the nonmetro area ranked last on the overall STEM industrial share, though not too far below the Flagstaff and Lake Havasu City metro areas.

Nonmetro Arizona was strongest in the science and science technician categories, ranking third in each, with a STEM share greater than the average for the state. The nonmetro area compared unfavorably in the computer and engineering categories, with its shares greater than those only in Metro Lake Havasu City. Nonmetro Arizona ranked last in each of the industrial categories.

Arizona's nonmetro area is compared to the state's seven metro areas on the change in the STEM share of aggregate earnings in the bottom part of Table 23. The change between 2005 and 2019 in the overall STEM occupational share in nonmetro Arizona ranked sixth among the eight substate areas, roughly similar to the shares in three of the five less-populous metro areas. The change between 2001 and 2019 in the overall STEM industrial share in nonmetro Arizona ranked fifth among the eight substate areas, with a loss not as great as in the state's two major metro areas.

On the change in the STEM share over time, nonmetro Arizona was strongest in the engineering and engineering technician categories, ranking second in each. The nonmetro area compared unfavorably in the computer and science technician categories.

Based on employment, nonmetro Arizona's overall STEM share in 2019 of 2.85 percent was marginally higher than the U.S. nonmetropolitan area figure of 2.79 percent. Of the 47 states with a nonmetropolitan area, Arizona ranked 20th. The change between 2005 and 2019 in Arizona's nonmetro share of -0.05 percentage points was inferior to the gain of 0.16 percentage points in the U.S. nonmetro area; Arizona ranked 44th.

TABLE 23
STEM SHARE OF AGGREGATE EARNINGS IN ARIZONA'S METROPOLITAN AND NONMETROPOLITAN AREAS

	Metropolitan Areas							
	Phoenix	Tucson	Flagstaff	Lake Havasu City	Prescott	Sierra Vista	Yuma	Nonmetro Arizona
2019								
Occupational Total	10.34%	11.57%	5.59%	2.92%	4.07%	12.21%	5.27%	4.51%
Computer	6.61	6.03	2.06	1.12	1.64	7.59	2.28	1.51
Math	0.29	0.12	0.04	0.03	0.03	0.20	0.15	0.08
Engineering	2.32	3.76	1.49	1.33	1.62	2.91	1.54	1.45
Engineering Technician	0.71	0.60	0.30	0.22	0.33	0.69	0.57	0.43
Science	0.27	0.90	0.93	0.15	0.32	0.36	0.45	0.65
Science Technician	0.14	0.17	0.78	0.07	0.13	0.46	0.29	0.38
Industrial Total	10.18	14.69	1.19	1.39	2.97	7.47	3.77	0.74
Manufacturing	4.59	9.94	0.11	0.57	1.18	0.10	0.10	0.02
Services	5.59	4.75	1.07	0.82	1.79	7.36	3.67	0.72
Change Over Time*								
Occupational Total	1.56	1.13	-0.57	-0.20	0.15	1.13	0.89	-0.11
Computer	2.18	1.26	0.04	-0.12	0.47	0.98	0.24	-0.21
Math	0.18	0.07	0.00	0.02	0.02	0.07	0.06	0.02
Engineering	-0.40	0.03	-0.17	-0.01	-0.03	-0.09	0.37	0.19
Engineering Technician	-0.39	-0.33	-0.11	-0.10	-0.26	-0.01	0.10	0.04
Science	0.00	0.16	0.00	0.03	0.01	0.14	0.06	0.05
Science Technician	0.00	-0.05	-0.34	-0.02	-0.05	0.04	0.07	-0.21
Industrial Total	-1.33	-0.61	0.03	-0.80	-0.03	1.44	1.20	-0.17
Manufacturing	-2.97	-1.27	-0.18	0.18	-0.13	-0.32	-0.65	-0.32
Services	1.64	0.663	0.21	-0.98	0.10	1.76	1.85	0.15

* Between 2005 and 2019 occupationally and between 2001 and 2019 industrially, measured as the percentage-point change.

Sources: Emsi (employment and earnings). Definition of STEM occupations and STEM-intensive industries produced by authors.

Based on the 2019 STEM employment share in the nonmetro areas, Arizona ranked between 11th and 16th in the occupational categories of computer, math, science, and science technology. The state ranked 30th in the engineering and engineering technician categories. Arizona ranked 14th on the 2005-to-2019 change in share in the nonmetro area in the engineering technician category. The state ranked between 22nd and 29th in the computer, math, and engineering categories, but only 39th in the science category and 46th in the science technician category.

County Not Reported

In 2019, Arizona's STEM share in the county not reported classification was greater than the national average, ranking eighth. The state ranked sixth in the computer category, between 11th and 23rd in the math, engineering, and engineering technician categories, and between 30th and 41st in the science and science technician categories.

Arizona also ranked eighth in the 2005-to-2019 change in STEM share in the county not reported classification. The state ranked fifth in the computer category, 13th in the math category, and between 38th and 44th in the engineering, engineering technician, science, and science technician categories.

Geographic Variations in STEM Economic Activity

This section provides an initial examination of the reasons why the STEM shares of total employment and total aggregate earnings vary so much by metropolitan area. The STEM share of total employment in 2019 ranged from 1.42-to-23.40 percent across the 384 metro areas. The median was 3.84 percent.

Educational Attainment

The STEM share is highly correlated to educational attainment, as measured by the share of employed individuals between the ages of 25 and 64 who have earned at least a bachelor's degree.[22] The educational attainment variable ranged from 15.7-to-66.3 percent across the 384 metro areas, with a median of 32.3 percent. The correlation between this measure of educational attainment and the STEM employment share is 0.66 across all 384 metro areas. The correlation is highest in size class 1 at 0.77. In SCs 2 and 3, the correlation is 0.70. The correlation drops across the three smallest size classes to 0.45 in SC6. Correlations between educational attainment and the STEM share of aggregate earnings are slightly lower.

The correlation between educational attainment and STEM intensity does not indicate cause and effect. Since so many STEM occupations require at least a bachelor's degree, the decision of a company with a high share of its workforce in STEM occupations to locate in a particular metro area will boost the educational attainment of the area. However, it also is likely that the location decision in part depends on the educational attainment of the metro areas under consideration prior to the company's location decision.

If it is assumed that educational attainment plays a role in determining the STEM intensity in a metro area, the importance of this factor can be estimated through a regression analysis in which

[22] The data come from Table B23006 of the American Community Survey (ACS) produced by the U.S. Department of Commerce, Census Bureau. In order to minimize sampling error, results for the five years from 2015 through 2019 were combined.

the STEM share is the dependent variable. Using educational attainment as the only explanatory variable, 44 percent of the variation in the STEM share of employment across the 384 metro areas is explained. The coefficient of the educational attainment variable is 0.173. Thus, an increase of 1 percentage point in the share of the employed population between the ages of 25 and 64 with at least a bachelor's degree adds 0.17 to the STEM share of total employment.

Using the same regression model for each of the six size classes, the explained share of the variation in the STEM share of employment ranges from 48-to-60 percent across the first three size classes, but is between 19-and-41 percent in the three smallest size classes. The coefficient of the educational attainment variable is greater in the larger size classes than in the smaller size classes, indicating that boosting educational attainment in large metro areas results in a greater increase in the STEM share than in small metro areas.

Other Factors

Other factors play a role in explaining the geographic variation in the STEM share, but the correlations between STEM intensity and each of these variables is much lower than the correlation with educational attainment:

- Metropolitan size. The correlation between the STEM share of employment and metro size as measured by employment is only 0.25.
- The region of the country in which a metro area is located. The nine regions of the country defined by the U.S. Census Bureau were used to create eight dummy variables for inclusion in the regression equation.[23]
- The presence of research universities. A research university is a doctoral university with high research activity, as measured by four indicators: research and development expenditures in science and engineering; other R&D expenditures; science and engineering research staff; and number of doctoral conferrals. A university with very high research activity is designated as "R1" and a university with high research activity is designated as "R2."The research university measure was calculated as follows:
    - The number of R1 universities was multiplied by a factor of 1.5 and added to the number of R2 universities.
    - This weighted sum was divided by the population (in millions) of the metro area.

  The correlation between the STEM share and the research university variable is only 0.22. Only 145 metro areas have a research university. Thus the median value of the research university variable is zero; the highest value is 16.1.
- Typology of universities in a metro area. Ehlenz and Mawhorter (2021) created a typology of the metropolitan geography of higher education by placing each metropolitan area into one of six categories based on its number, size, type, and quality of higher education institutions offering a four-year degree. Some metro areas do not have any such institutions and thereby form a seventh category. Six dummy variables were created for inclusion in the regressions.

[23] A dummy variable has a value of zero or one. For example, Metro New York City is in the Middle Atlantic region. The dummy variable for Metro New York receives a value of one for this region, while each of the other dummy variables receive a value of zero. Each of the eight dummy variables included in the regression are expressed relative to the dummy variable not included (in this case, the West South Central region, which has the worst negative correlation with STEM intensity).

Significant correlation is present between the educational attainment variable and each of these other independent variables. Thus, the educational attainment variable cannot be used in conjunction with other variables in a regression. For instance, including educational attainment with the metro size and research universities variables in a single equation causes the sign of the latter two variables to become negative.

Initially, univariate regressions — those with just one independent variable — were run using all 384 metro areas. With metro size as measured by employment as the only independent variable, only 5.9 percent of the variation in the STEM share of employment is explained (the adjusted R-squared is 0.059), but this relationship is statistically significant with more than 99 percent confidence. The coefficient of the employment variable indicates that on average a metro area with 1 million more residents than another would have a STEM share 0.67 percentage points higher.

Using the set of dummy variables for region as the only independent variable, only 2.4 percent of the variation in the STEM share of employment is explained; this relationship is significant with 97 percent confidence. The STEM share is highest in the East North Central, Mountain, and New England regions and lowest in the West South Central and East South Central regions.

With research universities as the only independent variable, only 4.5 percent of the variation in the STEM share of employment is explained. This small adjusted R-squared value is significant at more than 99 percent confidence, but the adjusted R-square value is generally not significant when the same regression model is applied to each of the six size classes. The coefficient of the research university variable is 0.193.

A slightly better fit is attained by including the dummy variables for the typology created by Ehlenz and Mawhorter (2021). Using this set of dummy variables as the only independent variable results in an R-squared of 0.132. The coefficients of the dummy variables are sensible, and indicate the degree to which each of the typology's categories increase STEM share relative to a metro area with no four-year university:

- "Super Center:" 3.57. These metro areas have numerous higher education institutions of varying size and type (for example, doctoral universities, master's universities, baccalaureate universities, etc.), with no individual institution dominant.
- "Major Center:" 2.20. These metro areas are similar to super centers, but on a smaller scale.
- "Multi-College Town:" 1.89. Relative to metro areas classified as "centers," college towns are more highly dominated by one university (or a few in the case of multi-college towns).
- "Strong College Town:" 1.49. These metro areas are dominated by one highly reputable large institution, such as a public land-grant university.
- "Minor Center:" 0.88. These metro areas not only have fewer institutions than major centers, but the institutions are of a lesser quality (as measured, for example, by selectivity of student admittance and graduation rates).
- "Weak College Town:" 0.65. These metro areas are dominated by one smaller institution of lower quality.

Expanding the regressions to include more than one independent variable only slightly boosts the explanatory power. For example, a regression using metro size and research universities explains only 11 percent of the variation in the STEM share of employment across the 384 metro areas. The addition of the regional dummy variables improves the explanatory power to only 13 percent.

The best fit without using the educational attainment variable is achieved with the research university variable and the typology dummy values as independent variables. The explanatory power is 15 percent, with both the research university variable and the typology variable statistically significant with the proper sign.

In conclusion, little of the geographic variability in STEM intensity can be explained by metro size, region, the presence of research universities, and the typology of universities in a metro area — even though these variables are significantly related to the STEM share. A stronger fit is present between STEM intensity and educational attainment, but it is not clear how much of this relationship is due to higher educational attainment being the cause of higher STEM intensity.

OTHER STEM INDICATORS FOR ARIZONA AND THE NATION

In this section, STEM indicators other than employment and earnings are presented for Arizona and the United States. Six indicators are presented, three related to human capital and three related to financial capital.

Human Capital

The economic literature on regional economic growth stresses the importance of high-quality human capital in the workforce. Graduate education at the state's universities is a source of this talent. Science and engineering specialties are of particular importance to innovation.

The number of graduate students enrolled and the number of postdoctoral appointees in science, engineering, and health disciplines in doctorate-granting institutions form the first indicator. The numbers are reported by university and have been tallied into state and national totals. The source is the National Science Foundation (NSF). Annual data go back to 1972; the latest data are for 2018.

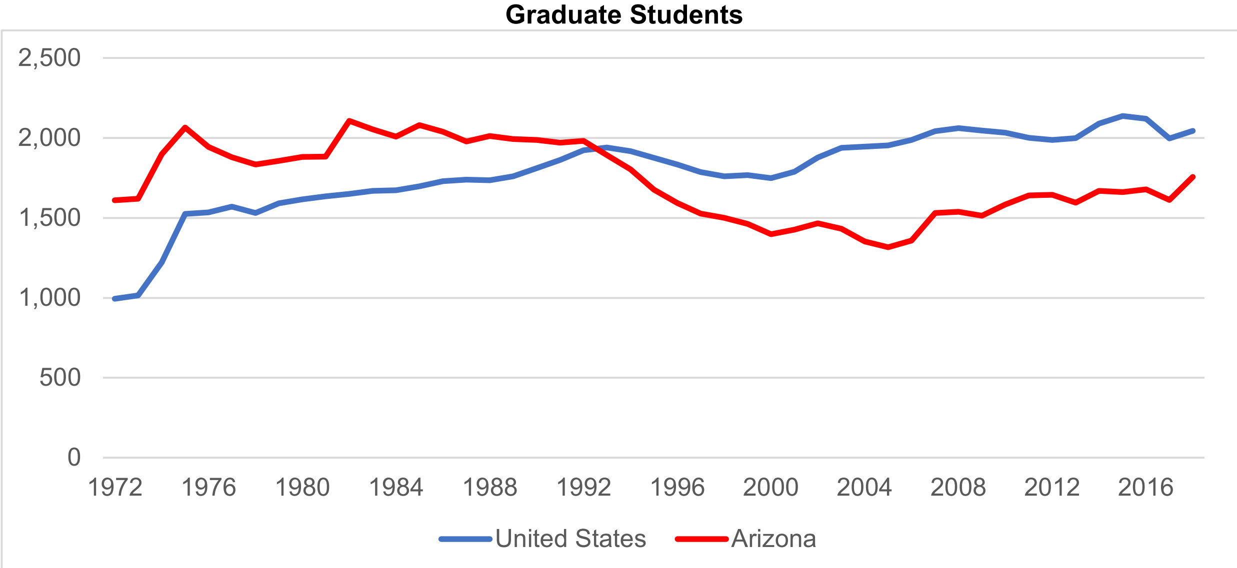
Chart 7 presents the numbers of graduate students and postdoctorates per 1 million residents. Nationally, the per capita number of graduate students in science, engineering, and health disciplines rose through the 1970s and 1980s but has hardly increased since the early 1990s. Historically, Arizona had a greater per capita number of graduate students than the U.S. average. Arizona's figure in 1972, the first year of data, was 1.62 times the national average. This ratio declined through 2005, with Arizona's per capita number falling below the national average in 1993 and reaching a trough of only 67 percent of the national average in 2005. Some improvement has occurred since 2005 in Arizona relative to the nation, with the 2018 ratio at 0.86, the highest since 1996. In 2018, there were 1,756 graduate students in science, engineering, and health fields per one million residents in Arizona, compared to the national average of 2,046.

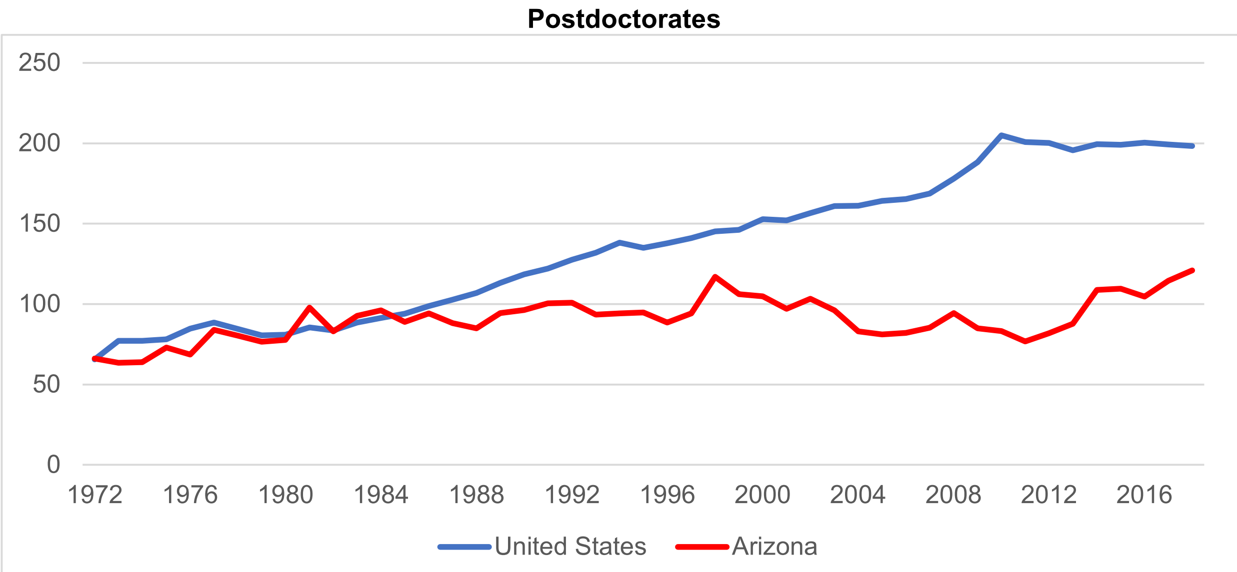
Nationally, the per capita number of postdoctorates in science, engineering, and health disciplines increased considerably from 1972 through 2010, but has slipped a bit since then. The per capita number historically was similar in Arizona to the nation. Arizona began to fall behind the nation in the mid-1980s, dropping as low as 38 percent of the national average in 2011. Since then, some improvement has occurred in Arizona relative to the nation, with the 2018 ratio at 0.61, the highest since 2002. In 2018, there were 121 postdoctorates in science, engineering, and health fields per one million residents in Arizona, compared to the national average of 198.

The second indicator is the number of employed doctoral scientists and engineers, expressed per one million residents (see Chart 8). These data also are from the NSF, with figures available every two or three years; the latest data are for 2017. Nationally, the total per capita number steadily increased from the earliest data for 1993 through 2017. Arizona's per capita number has consistently been about 30-to-35 percent below the national average. In 2017, there were 1,732 employed doctoral scientists and engineers per one million residents in Arizona, compared to the national average of 2,508.

Looking only at doctoral scientists and engineers employed in science and engineering occupations, the findings are similar. The per capita number in Arizona has consistently been

CHART 7
NUMBER IN SCIENCE, ENGINEERING, AND HEALTH FIELDS PER 1 MILLION RESIDENTS IN ARIZONA AND THE UNITED STATES

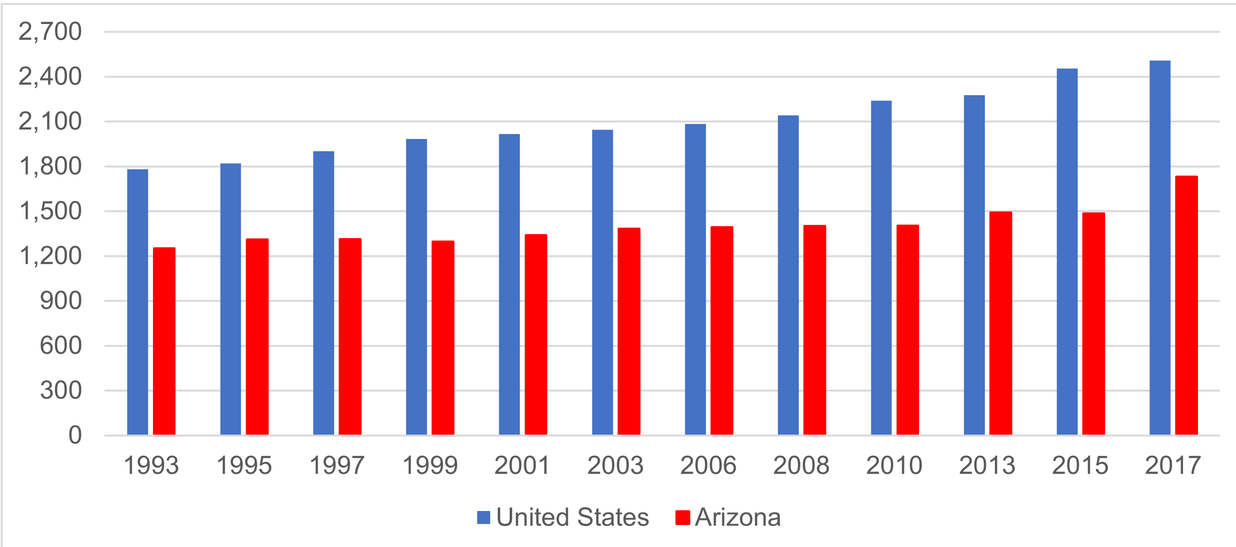




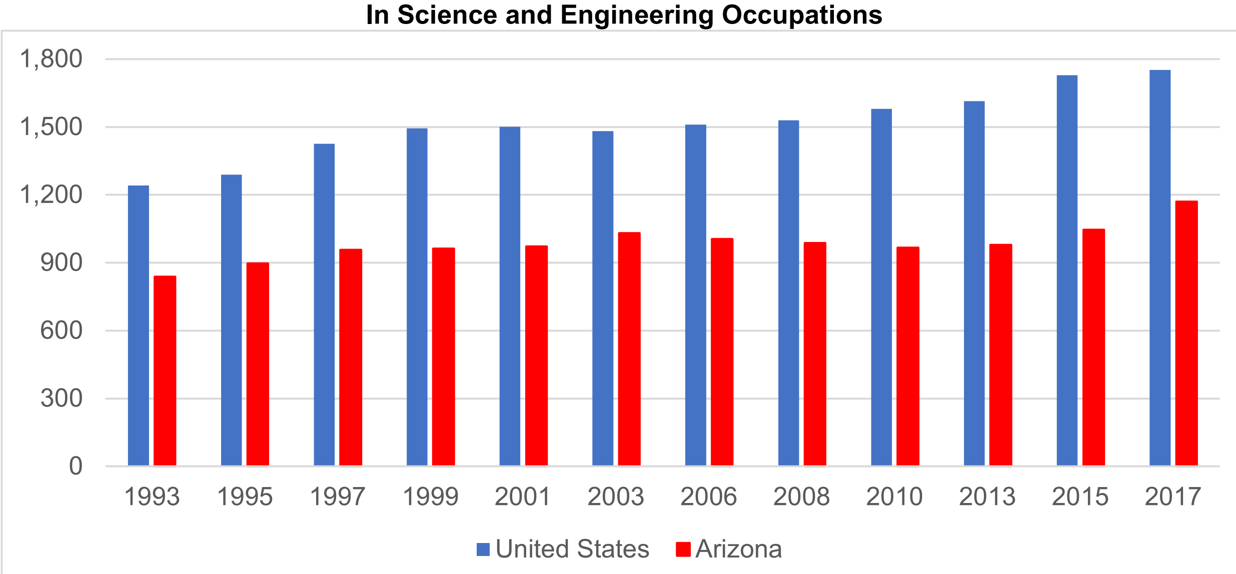
Sources: National Science Foundation (number of graduate students and postdoctorates) and U.S. Department of Commerce, Census Bureau (population).

CHART 8
NUMBER OF EMPLOYED DOCTORAL SCIENTISTS AND ENGINEERS PER 1 MILLION RESIDENTS IN ARIZONA AND THE UNITED STATES

Total



In Science and Engineering Occupations



Sources: National Science Foundation (number employed) and U.S. Department of Commerce, Census Bureau (population).

below the national average by about 30-to-35 percent, with Arizona keeping pace with the gains in the national per capita number. In 2017, there were 1,171 doctoral scientists and engineers employed in science and engineering occupations per one million residents in Arizona, compared to the national average of 1,753.

The third indicator in the human capital category is the number of patents granted. Inventive activity is a proxy for the quality of the innovation environment. Innovation requires both ability and creativity. Thus, the number of patents granted is one measure of a region's ability to innovate. Regions where companies, universities, and individuals are engaged in innovation should have more patents granted.

The source of the patent data is the U.S. Patent and Trademark Office, which provides annual figures by state going back to 1963. Only "utility" patents, also known as "patents for inventions," with a United States origin are included. The patent data have some limitations. Many patent applications list more than one inventor. The geographic allocation of a patent granted is determined by the residence of the first-named inventor at the time of the grant. The geographic distribution of patents could be different if the residences of all inventors were considered. A simple count of number of patents granted does not distinguish between patents with considerable near-term commercialization potential and those with more nebulous marketability.

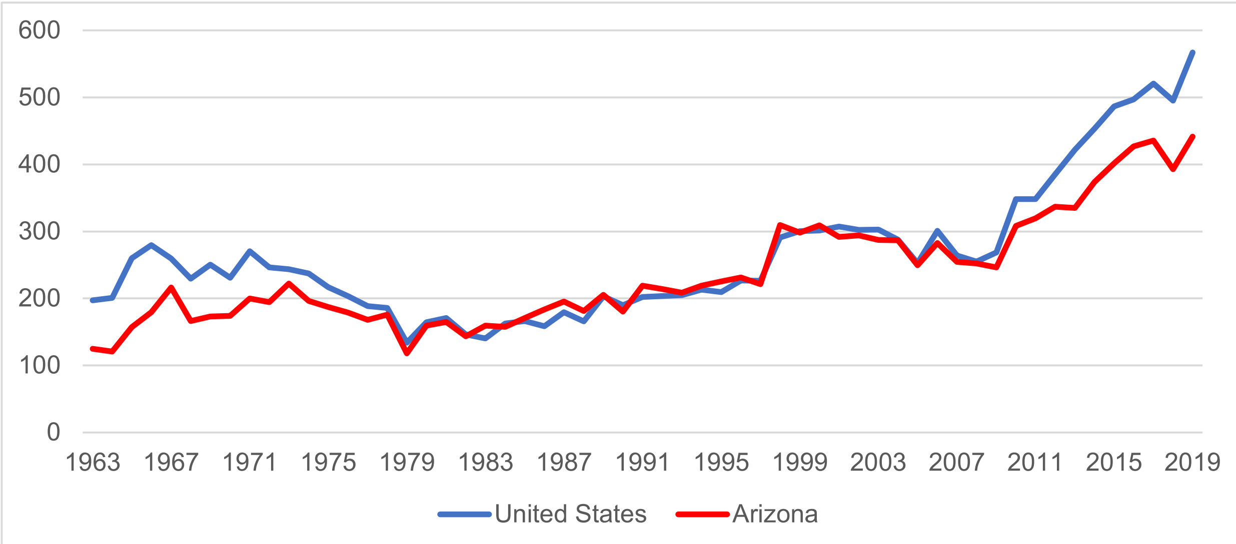
As seen in Chart 9, the number of patents granted in the United States per 1 million residents has increased substantially over time, with most of the increase occurring since 2010. In the 1960s and 1970s, Arizona's per capita number was less than the national average, by as much as 40 percent. From the early 1980s through 2008, Arizona's per capita number was similar to the national average, but since then Arizona has again fallen behind. The shortfall widened to 22 percent in 2019, when Arizona's figure was 442 patents granted per one million residents, compared to the national average of 567.

Financial Capital

The first of the three indicators of financial capital is research and development (R&D) funding. The importance of R&D investment is a central theme of the economic literature on economic growth. Economic analysis suggests that R&D investment is crucial for attaining increases in labor productivity that ultimately translate into improvements in prosperity. R&D investment is at the center of an innovation strategy and this indicator measures the extent to which the state's businesses and universities are engaged in research and development.

The R&D data, which come from the NSF, are derived from a survey. The industrial data in particular are subject to survey error and also are subject to nonresponse bias as companies may be reluctant to disclose the amount of R&D that takes place at any particular facility. Industrial R&D by state was reported only for selected years prior to 1997; interpolated values for the missing years are shown in Chart 10. The dollar value of R&D is expressed per $1 million of gross domestic product (GDP), which is reported by the U. S. Department of Commerce, Bureau of Economic Analysis.

CHART 9
NUMBER OF PATENTS GRANTED PER 1 MILLION RESIDENTS IN ARIZONA AND THE UNITED STATES



Sources: U.S. Patent and Trademark Office (patents) and U.S. Department of Commerce, Census Bureau (population).

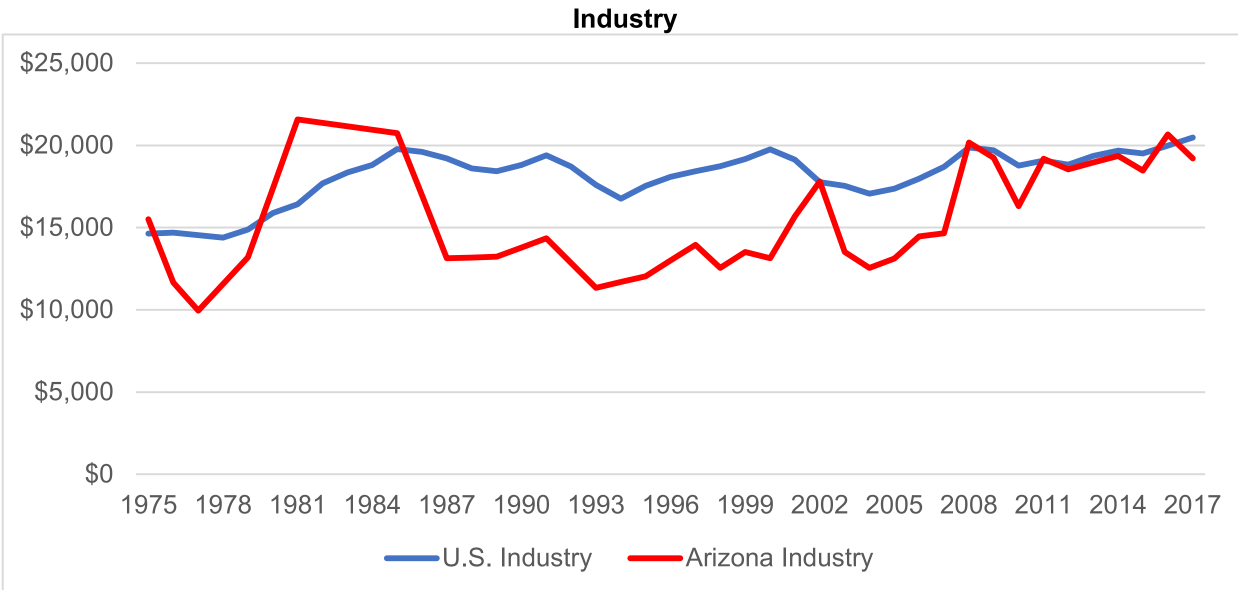
In Chart 10, industry R&D spending is presented for 1975 through 2017 and academic R&D expenditures are shown for fiscal year (FY) 1972 through FY 2018. (For example, fiscal year 2018 ran from July 1, 2017 through June 30, 2018.) Industry R&D spending is substantially greater than academic R&D spending, by a factor of more than 5 in recent years.

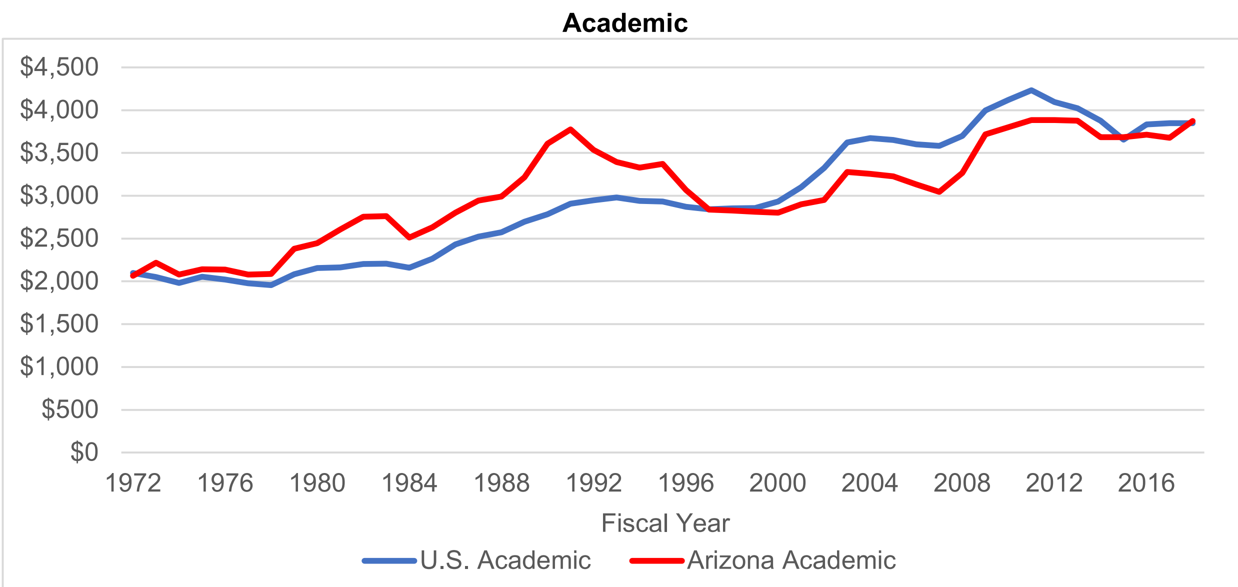
Nationally, industry R&D investment per $1 million of GDP increased in the late 1970s and early 1980s, and has fluctuated since then with little trend, though the 2016 and 2017 figures were the highest on record. Arizona's industry R&D investment per $1 million of GDP has varied substantially over time relative to the national average. Arizona's figure generally was considerably below the national average through 2007, though it was higher during the early 1980s. Since 2008, Arizona's figure has been similar to the national average. In 2017, industry research and development funding per $1 million of GDP was $19,198 in Arizona, 6.2 percent less than the national figure of $20,473.

Academic R&D spending relative to GDP rose nationally from the mid-1980s through FY 2011, but has dropped since then. Arizona's figure was above average from FY 1973 through FY 1996. Since then it has ranged from about the same as the U.S. average to 15 percent lower. In FY 2018, research and development funding per $1 million GDP was marginally higher at Arizona-based academic institutions ($3,875) than the national average ($3,847).

Academic R&D is divided into five categories by source of funding. Nationally, the federal government has been the largest source, followed by institutions, in each year. As seen in Chart 11, federal R&D spending relative to GDP rose nationally from the mid-1980s through FY 2011 but has dropped since then. Other than a few years from the early 1980s through early 1990s,

CHART 10
RESEARCH AND DEVELOPMENT FUNDING PER $1 MILLION OF GROSS DOMESTIC PRODUCT IN ARIZONA AND THE UNITED STATES

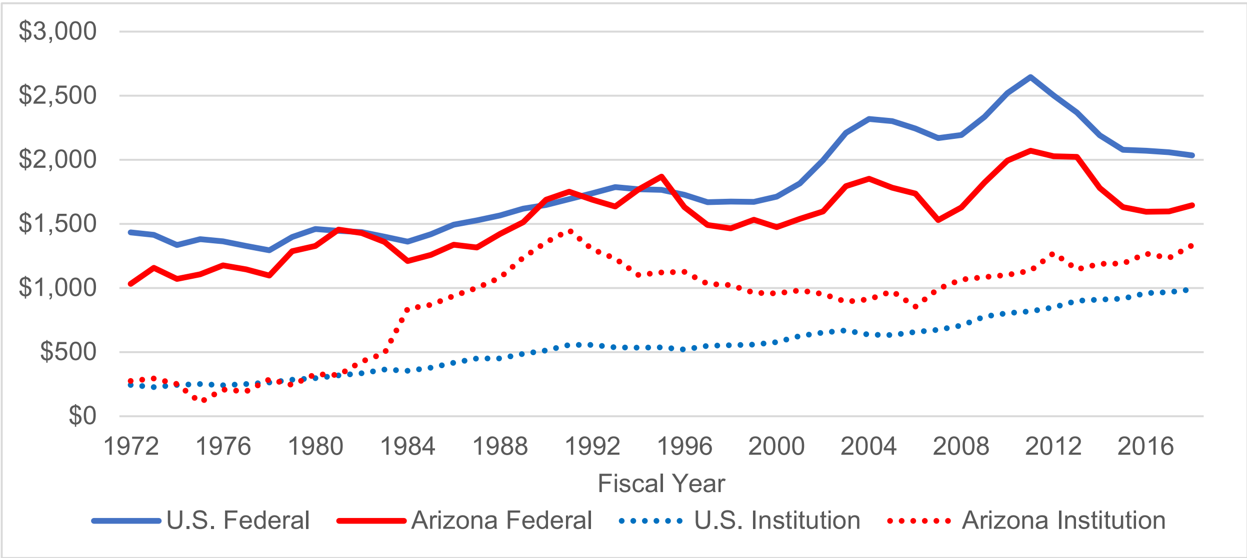




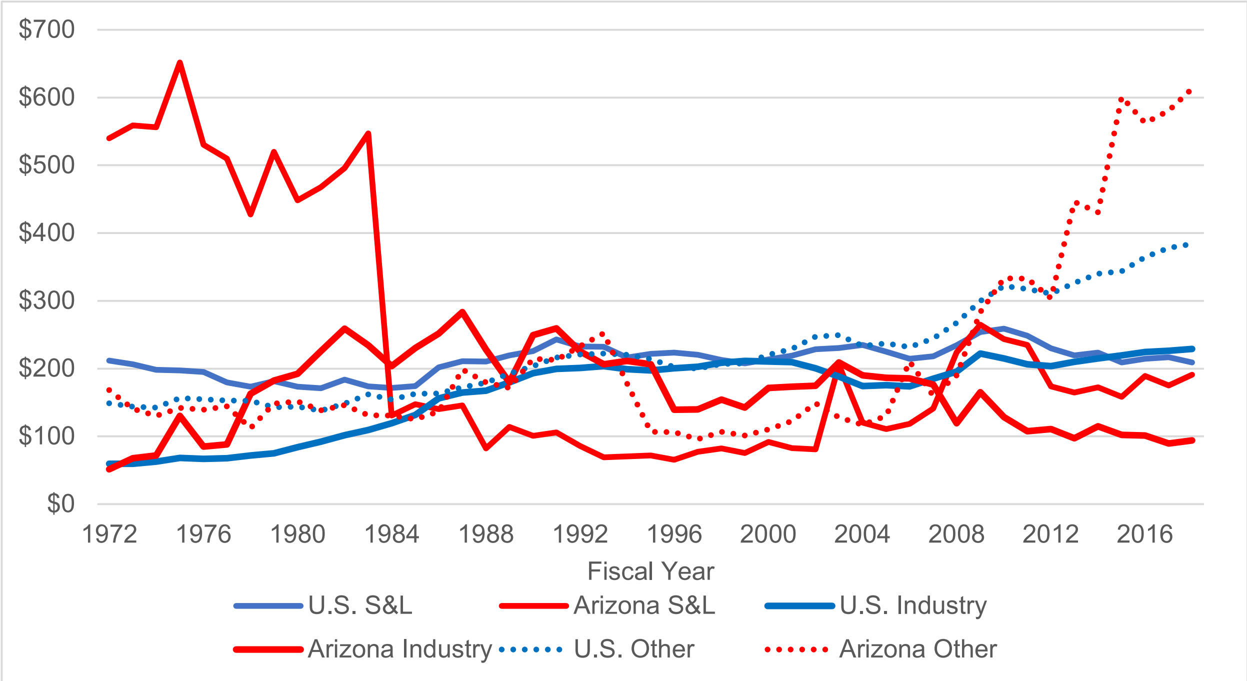
Sources: National Science Foundation (R&D) and U.S. Department of Commerce, Bureau of Economic Analysis (GDP).

CHART 11
ACADEMIC RESEARCH AND DEVELOPMENT FUNDING BY SOURCE PER $1 MILLION OF GROSS DOMESTIC PRODUCT IN ARIZONA AND THE UNITED STATES

Federal and Institution



Other Sources



Note: “S&L” refers to state and local governments.

Sources: National Science Foundation (R&D) and U.S. Department of Commerce, Bureau of Economic Analysis (GDP).

federal funding relative to GDP has been lower in Arizona than the nation. In FY 2018, federal funding per $1 million of GDP amounted to $2,035 in the United States — 19 percent higher than Arizona's figure of $1,645.

Institutional R&D funding has steadily increased nationally. In Arizona, the figure went from similar to the nation during the 1970s to far above average from the mid-1980s through late 1990s. The differential has narrowed since then, but in FY 2018, Arizona's figure of $1,332 per $1 million of GDP still was 35 percent higher than the national figure of $989.

The other sources of academic R&D have been considerably less than the federal and institutional sources in recent years. Nationally, state and local government funding per $1 million of GDP has been flat since the mid-1980s. Arizona's figure went from far above to well below the national average, but in FY 2018 was only 9 percent below average. Industry contributions to academic R&D relative to GDP rose nationally during the 1970s and 1980s, but have climbed only a bit since then. Arizona's figure has varied relative to the nation but has been far below average since FY 2008. The differential was 59 percent in FY 2018. R&D funding from other sources has increased nationally relative to GDP. After being relatively close to the U.S. figure through the early 1990s, Arizona's figure dropped far below average, but since FY 2013 has been considerably above average, by 60 percent in FY 2018.

Innovation grants are the second indicator of financial capital. The U.S. Small Business Administration (SBA) administers two competitive programs to distribute federal research and development funds to small, high-technology, innovative businesses: Small Business Innovation Research (SBIR, since 1983) and Small Business Technology Transfer (STTR, since 1998). The SBIR program encourages small businesses to explore their technological potential and provides an incentive to profit from commercialization. The STTR is a related program that is designed to facilitate the transfer of technological innovation from nonprofit research institutions to small commercial enterprises. It primarily is a program linking research universities to commercialization efforts.

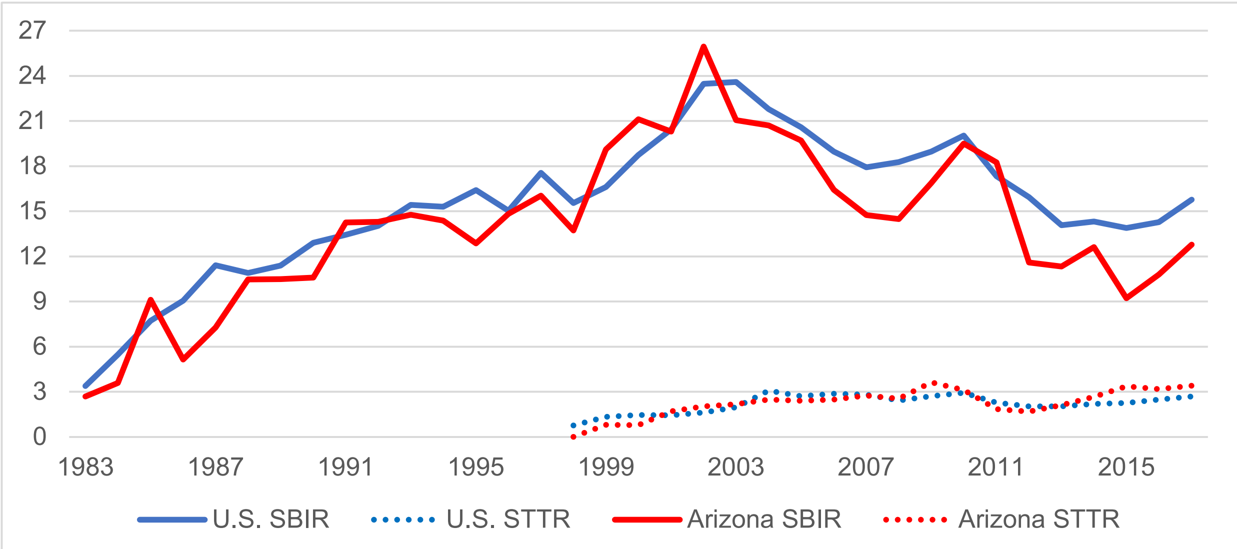
The ability of a state to attract a significant share of SBIR grants reflects the business climate for innovative activity. Monitoring the pace of SBIR grant activity may be a good way to gauge the extent to which the state's entrepreneurial community is engaged in innovative entrepreneurship that can be wealth enhancing. The STTR program is one measure of the proclivity of the state's research institutions to pursue opportunities for commercialized innovation initiatives.

Innovation grant data are presented in three ways: the number of grants per one million residents, the inflation-adjusted value of the grants per 1,000 residents, and the value of the grants per $1 million of gross domestic product (see Chart 12). The three measures provide a consistent picture of the comparison between Arizona and the nation.

Concentrating on the value of grants per $1 million of GDP, the annual SBIR value has been erratic nationally, but trended up from the inception of the SBIR program through 2004. Values relative to GDP have been lower since then. The value of STTR grants is much less than the value of SBIR grants. Annually, the value relative to GDP has fluctuated nationally, but trended up from the inception of the STTR program through 2010 and has not changed much since then.

CHART 12
INNOVATION GRANTS IN ARIZONA AND THE UNITED STATES

Number of Grants Per 1 Million Residents



Value of Grants in Inflation-Adjusted (2017) Dollars Per 1,000 Residents

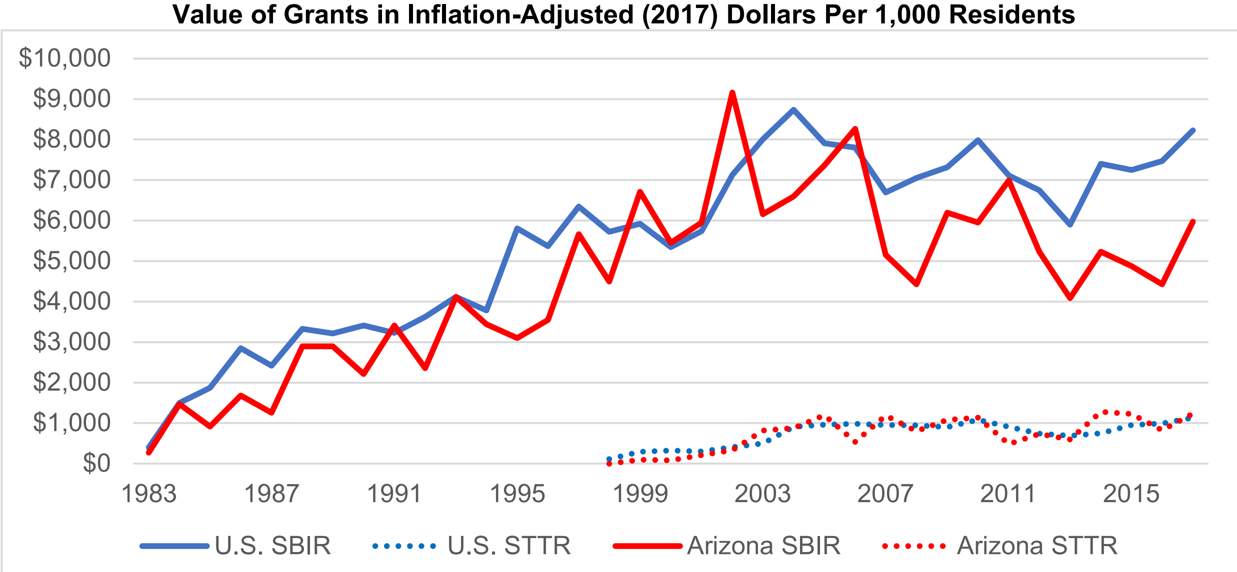


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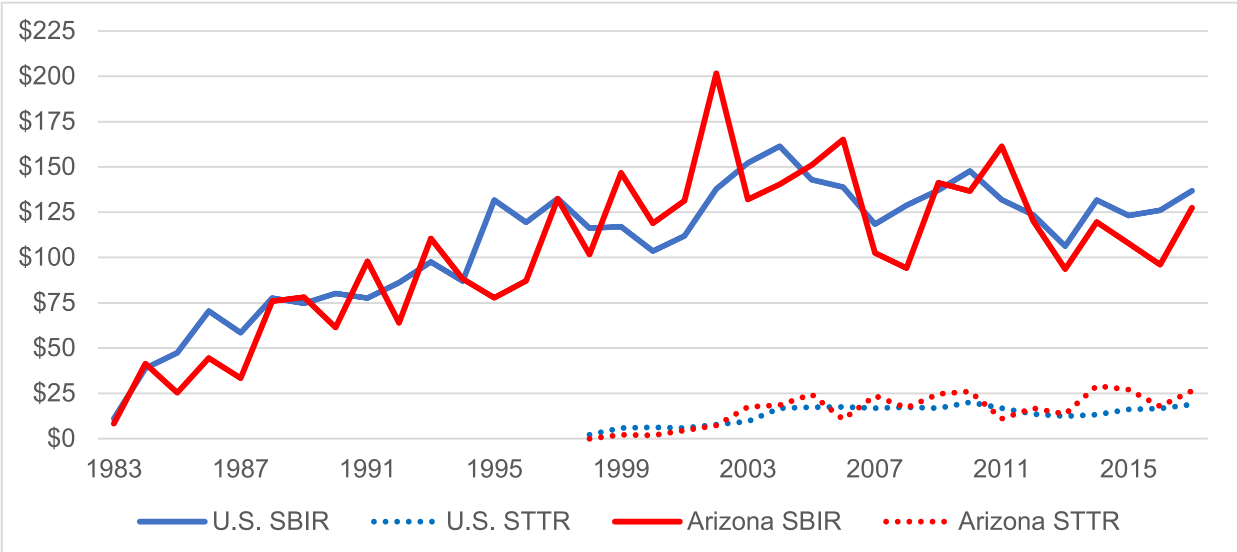
CHART 12 (continued)
INNOVATION GRANTS IN ARIZONA AND THE UNITED STATES

Value of Grants Per $1 Million of Gross Domestic Product



Sources: U.S. Small Business Administration, Office of Technology (grants), U.S. Department of Commerce, Bureau of Economic Analysis (GDP and gross domestic product implicit price deflator), and U.S. Department of Commerce, Census Bureau (population).

Relative to the national average, Arizona's value of SBIR grants per $1 million of GDP has fluctuated from higher to much lower. Arizona had a shortfall of 7 percent in 2017. Arizona's value of STTR grants per $1 million of GDP also has fluctuated relative to the nation, from considerably higher to much lower. Arizona's figure was higher from 2012 through 2017, with a differential in 2017 of 40 percent.

The third indicator of financial capital is venture capital. Venture capitalists invest in firms that have a high potential for growth but are not ready to do an initial public offering of stock. The investments tend to be both high risk and high return. Venture capital activity can be used to measure the number of potentially high-growth firms being started. These typically are innovative high-technology firms, such as biotechnology enterprises.

The source of the venture capital data is the PricewaterhouseCoopers/National Venture Capital Association MoneyTree(tm) Report. The quarterly data from this report are aggregated into annual data from 1995 through 2019. The venture capital data are based on publicly reported deals and may not be representative of total venture capital invested. For Arizona, considerable variability from year to year results from the small number of deals.

The same three measures used for innovation grants are used for venture capital (see Chart 13). Each shows a similar pattern. Based on the value per $1 million of GDP, venture capital rose nationally from 1995 through 2000, reaching a very high peak. It dropped sharply over the next two years, then remained relatively low through 2013. Since then, higher values have been measured. Venture capital relative to GDP has been far less in Arizona than the national average in each year. Since the mid-1990s, Arizona's value has ranged from just 11 percent to 68 percent of the U.S. figure. In 2019, Arizona's value relative to GDP was 15 percent of the U.S. average.

CHART 13
VENTURE CAPITAL IN ARIZONA AND THE UNITED STATES

Number of Deals Per 1 Million Residents

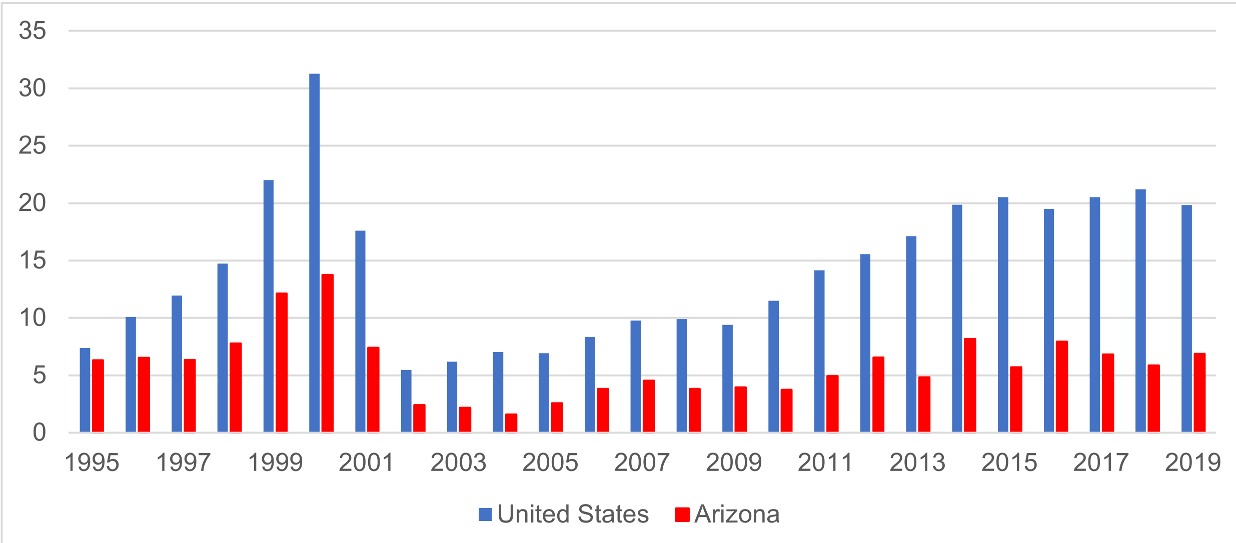


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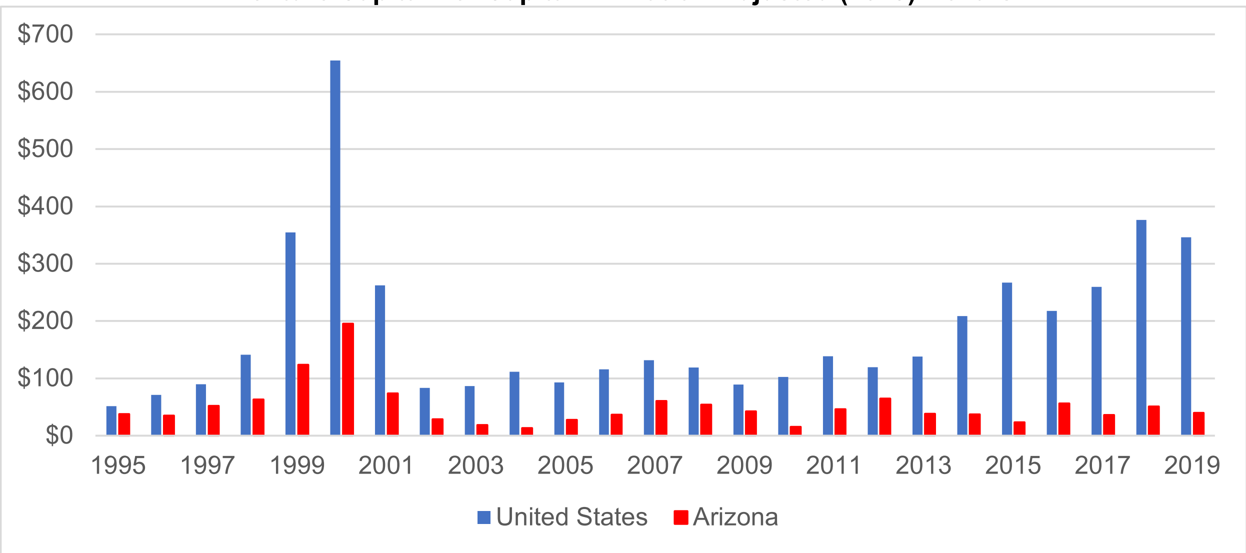
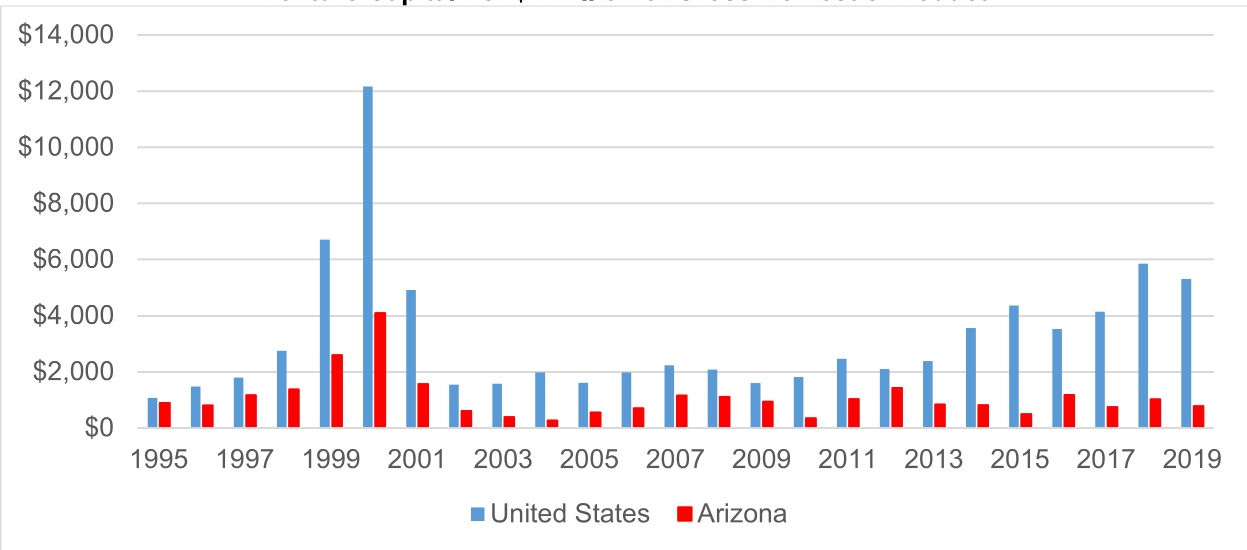
CHART 13 (continued)
VENTURE CAPITAL

Venture Capital Per Capita in Inflation-Adjusted (2019) Dollars



Venture Capital Per $1 Million of Gross Domestic Product



Sources: PricewaterhouseCoopers MoneyTree Report (venture capital), U.S. Department of Commerce, Bureau of Economic Analysis (GDP and gross domestic product implicit price deflator), and U.S. Department of Commerce, Census Bureau (population).

ECONOMIC IMPACTS OF STEM ECONOMIC ACTIVITIES IN ARIZONA

This chapter estimates the economic impacts of STEM activities in Arizona's economy, based on the industrial definition of STEM. Several simulations are presented, including current impacts, projected future impacts, and scenarios assuming various changes to STEM activities in the state.

Based on the industrial definition, STEM activities predominantly are "traded" economic activities — those whose products and services are sold to customers outside the local region. The sale of goods and services to customers from outside the region imports money into the regional economy that would otherwise not be present. In contrast to traded activities, nontraded (or "local") economic activities are location specific since they sell their goods and services to regional customers. While an integral part of a regional economy, nontraded activities do not import money into the regional economy. Their presence in the region is due to traded activities — the expenditures made locally by companies selling traded goods and services and by the employees of these businesses. In this way, traded activities "drive" the regional economy while nontraded activities respond to the growth occurring in traded activities.

A disproportionate share of those working in STEM occupations are employed by companies that export their products and services. Moreover, earnings per job in STEM activities are much higher than average. Thus, STEM activities have a strong economic impact. These contributions include direct effects resulting from hiring STEM workers and multiplier effects that arise when spending on payroll, general procurement, and construction ripples through the local economy.

The REMI PI+ economic impact model — see Appendix C for a description — was used to estimate multiplier effects. The REMI model is the preferred choice versus an input-output model such as IMPLAN because it is dynamic and it incorporates agglomeration[24] effects and congestion[25] effects, which makes it more suitable to be used for a multiyear economic impact study.

Results are reported in terms of jobs (total employment and private nonfarm employment), gross domestic product (GDP), earnings by place of work, and state and local government tax payments, all in Arizona. Employment over multiple years can be combined into "job years,"[26] a long-term measure of employment. All monetary amounts are reported in 2019 dollars.

Current Impacts

The contribution of STEM workers to the state's economy, based on 2019 employment data from Emsi for the 57 STEM-intensive industries displayed in Appendix B are reported in Table 24. During 2019, the presence of STEM workers in Arizona generated economic impacts of $74.5 billion in GDP, $53.3 billion in earnings, and $4.5 billion in state and local government tax payments. The 172,621 STEM workers supported an additional 474,050 workers, for a total employment impact of 646,671 jobs in all sectors of the economy, of which 619,309 jobs (95.8

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[24] Agglomeration effects occur when a large industry cluster exists in an area, creating a large market for certain specialized skills and leading to increases in productivity.

[25] Congestion effects occur because the increase in the size of an industrial cluster may lead to cost increases in the region, such as land prices, wages, and other local prices.

[26] It is important to distinguish the term "job years" from "jobs" in the impact total. A job year is equivalent to one person having a job for one full year. For example, a person employed at a company for five consecutive years represents a single job but five job years of employment.

TABLE 24
ECONOMIC IMPACTS OF STEM WORKERS, ARIZONA, 2019

	Total Employment (Jobs)	Private Nonfarm Employment (Jobs)	Gross Domestic Product (Millions)	Earnings by Place of Work (Millions)	State and Local Government Tax Payments (Millions)
2019	646,671	619,309	$74,510.9	$53,281.9	$4,529.0

Sources: REMI, based on Emsi employment. Proportion of earnings paid in state and local government taxes from Institute on Taxation & Economic Policy, Who Pays? A Distributional Analysis of the Tax Systems in All 50 States, October 2018, http://www.itep.org/whopays/. Definition of STEM-intensive industries produced by authors.

percent) were in private nonfarm sectors. To put it in perspective, these impacts represent 19.9 percent of Arizona's total employment as counted by Emsi and 20.1 percent of Arizona's GDP.

The employment multiplier of STEM jobs — calculated as the employment in non-STEM sectors created by the spending of STEM workers compared to STEM jobs — equals 2.75. This means that every STEM job in Arizona creates an additional 2.75 jobs in other sectors of the Arizona economy, for a total of 3.75 jobs.

The estimate of state and local government tax payments resulting from STEM industrial employment in Arizona does not come from REMI. These tax payments are assumed to be equal to 8.5 percent of REMI's total earnings of $53.3 billion, The 8.5 percent is an Arizona-specific figure calculated by the Institute on Taxation & Economic Policy for those earning between $55,000 and $96,400 per year. The average earnings of the 646,671 workers dependent on STEM employment is $82,394.

Impacts Had Arizona Not Disproportionately Lost STEM Jobs

Prior to 1990, the industrial STEM share in Arizona was considerably greater than the national average. The differential has narrowed since then, primarily due to disproportionately large job losses in Arizona in computer and electronic product manufacturing. Declines also have occurred in aircraft manufacturing. This section estimates the economic impact to the state of these historical losses of STEM jobs.

The **first historical simulation**, presented in Table 25, assumes that STEM employment in Arizona in 2019 was 25,800 more than the actual figure of 172,621. The 25,800 figure is obtained by comparing the STEM employment share in Arizona to the national average in 2001 (the first year of data from Emsi), and assuming that Arizona's STEM share had not declined versus the nation since 2001. In 2001, the STEM share in Arizona of 5.93 percent was 28 percent higher than the national average of 4.63 percent. In 2019, Arizona's share of 5.32 percent was only 11 percent higher than the national average of 4.81 percent.

Had this disproportionate loss of jobs not occurred in Arizona, in 2019 the state's GDP would have been $11.1 billion higher, with earnings $7.9 billion higher, tax payments $672 million higher, and 96,407 more jobs in all sectors (of which 92,237 jobs would have been in private

TABLE 25
ECONOMIC IMPACT OF MAINTAINING STEM SHARE OF EMPLOYMENT IN ARIZONA RELATIVE TO THE NATIONAL AVERAGE, 2019

	Total Employment (Jobs)	Private Nonfarm Employment (Jobs)	Gross Domestic Product (Millions)	Earnings by Place of Work (Millions)	State and Local Government Tax Payments (Millions)
2019	96,407	92,237	$11,116.2	$7,912.3	$672.5

Sources: REMI, based on Emsi's employment estimates. The proportion of earnings paid in state and local government taxes is from the Institute on Taxation & Economic Policy, "Who Pays? A Distributional Analysis of the Tax Systems in All 50 States," October 2018, http://www.itep.org/whopays/. Definition of STEM-intensive industries produced by authors.

nonfarm sectors). Employment would have been 2.8 percent higher and GDP would have been 3.0 percent higher.

The **second historical simulation,** presented in Table 26, uses data from the U.S. Department of Labor, Bureau of Labor Statistics to calculate the disproportionate job losses in Arizona since 1990 in computer and electronic product manufacturing (46,800) and in aerospace product and parts manufacturing (6,300). Based on the Emsi estimates from 2001 through 2019, job losses were spread across the industries in the computer and electronic product manufacturing classification, while in aerospace product and parts manufacturing, the job losses were limited to the aircraft portion of the classification — employment has continued to rise in the guided missile and space vehicle portion.

Thus, STEM industrial employment in Arizona in 2019 would have been 53,100 higher had Arizona's share in computer and electronic product manufacturing and aerospace product and parts manufacturing not declined versus the nation since 1990. Had this disproportionate loss of jobs not occurred in Arizona, in 2019 the state's GDP would have been $27.4 billion higher, with earnings $18.5 billion higher, tax payments $1.6 billion higher, and 206,558 more jobs in all sectors (of which 196,415 jobs would have been in private nonfarm sectors). Employment would have been 6.4 percent higher and GDP would have been 7.4 percent higher.

The employment multiplier for computer and electronic product manufacturing and aerospace product and parts manufacturing of 2.89 is somewhat higher than the multiplier for the sum of all industrial STEM activities.

Impacts From Expanding the STEM Presence in Arizona

The economic impacts from boosting the growth of industrial STEM activities in Arizona over the next decade are depicted in three scenarios. The **first future scenario** (Table 27) assumes that Arizona will add 1,000 STEM workers each year for the next 10 years — beyond the gains of the baseline forecast — resulting in an additional 10,000 STEM workers in the state in 2030. The additional jobs are allocated by industry based on the current distribution of STEM workers.

TABLE 26
ECONOMIC IMPACT OF MAINTAINING SHARE OF EMPLOYMENT IN ARIZONA RELATIVE TO THE NATIONAL AVERAGE IN COMPUTER AND ELECTRONIC PRODUCT MANUFACTURING AND IN AEROSPACE PRODUCT AND PARTS MANUFACTURING, 2019

	Total Employment (Jobs)	Private Nonfarm Employment (Jobs)	Gross Domestic Product (Millions)	Earnings by Place of Work (Millions)	State and Local Government Tax Payments (Millions)
2019	206,558	196,415	$27,433.0	$18,515.5	$1,573.8

Sources: REMI, based on U.S. Department of Labor, Bureau of Labor Statistics employment estimates. The proportion of earnings paid in state and local government taxes is from the Institute on Taxation & Economic Policy, "Who Pays? A Distributional Analysis of the Tax Systems in All 50 States," October 2018, http://www.itep.org/whopays/. Definition of STEM-intensive industries produced by authors.

TABLE 27
ECONOMIC IMPACT OF ADDING 1,000 STEM WORKERS PER YEAR IN ARIZONA FROM 2021 THROUGH 2030

	Total Employment (Job Years)	Private Nonfarm Employment (Job Years)	Gross Domestic Product (Millions)	Earnings by Place of Work (Millions)	State and Local Government Tax Payments (Millions)
2021	3,707	3,546	$440.3	$295.8	$25.1
2022	7,586	7,181	906.6	597.8	50.8
2023	11,607	10,905	1,410.4	922.3	78.4
2024	15,676	14,644	1,938.1	1,263.8	107.4
2025	19,628	18,248	2,473.9	1,613.6	137.2
2026	23,531	21,792	3,025.0	1,971.0	167.5
2027	27,418	25,309	3,593.9	2,339.9	198.9
2028	31,177	28,693	4,165.1	2,711.0	230.4
2029	35,295	32,420	4,789.6	3,112.3	264.5
2030	39,121	35,856	5,407.2	3,504.2	297.9
10-Year Total	217,746	198,594	28,150.1	18,331.8	1,558.2

Sources: REMI, based on Emsi employment. The proportion of earnings paid in state and local government taxes is from the Institute on Taxation & Economic Policy, "Who Pays? A Distributional Analysis of the Tax Systems in All 50 States," October 2018, http://www.itep.org/whopays/. Definition of STEM-intensive industries produced by authors.

The cumulative impact of these additional STEM workers on Arizona's economy during the 10-year time period would be a gain of $28.2 billion in GDP, an increase of $18.3 billion in earnings, a rise of nearly $1.6 billion in tax payments, and an increase of 214,746 in total job years in Arizona, of which 198,594 (92.5 percent) would be private nonfarm jobs.

The projected jobs multiplier rises from 2.71 in the first year to 2.91 in the 10th year — the 10,000 additional STEM jobs in the 10th year create an additional 29,121 jobs in various sectors of the economy, for a total of 39,121 jobs in Arizona in 2030.

The **second future scenario** (Table 28) also assumes that there will be an increase of 1,000 additional STEM workers per year in Arizona during the next 10 years, but it assumes that these workers will be distributed among three main industries which currently have little presence in the state: research and development, software publishers, and medicine manufacturing.

The impacts in this scenario are less than those in the first future scenario. For example, the 10-year total effect is 10.3 percent less on employment and 13.4 percent less on GDP. The projected jobs multiplier for these particular STEM activities is lower, rising from 2.39 in the first year to 2.51 in the 10th year.

TABLE 28
ECONOMIC IMPACT OF ADDING 1,000 STEM WORKERS PER YEAR IN SPECIFIC INDUSTRIES IN ARIZONA FROM 2021 THROUGH 2030

	Total Employment (Job Years)	Private Nonfarm Employment (Job Years)	Gross Domestic Product (Millions)	Earnings by Place of Work (Millions)	State and Local Government Tax Payments (Millions)
2021	3,392	3,257	$379.0	$270.5	$23.0
2022	6,974	6,632	785.4	552.9	47.0
2023	10,680	10,087	1,225.4	858.5	73.0
2024	14,406	13,534	1,685.1	1,178.6	100.2
2025	17,978	16,816	2,148.2	1,503.6	127.8
2026	21,506	20,046	2,625.6	1,839.4	156.3
2027	24,998	23,233	3,117.4	2,186.5	185.9
2028	28,342	26,270	3,608.7	2,535.7	215.5
2029	31,906	29,516	4,141.2	2,907.2	247.1
2030	35,124	32,423	4,659.7	3,266.7	277.7
10-Year Total	195,307	181,816	24,375.6	17,099.5	1,453.5

Note: The industries are research and development, software publishers, and medicine manufacturing.

Sources: REMI, based on Emsi employment. The proportion of earnings paid in state and local government taxes is from the Institute on Taxation & Economic Policy, "Who Pays? A Distributional Analysis of the Tax Systems in All 50 States," October 2018, http://www.itep.org/whopays/. Definition of STEM-intensive industries produced by authors.

The **third future scenario** (Table 29) assumes that there will be an increase in private-sector investment in STEM activities in Arizona during the next 10 years, in the amount of an additional $1 billion each year — a total of $10 billion in the 10th year of the simulation. This scenario is inspired by the announcement[27] made by TSM (Taiwan Semiconductor Manufacturing), a large manufacturer of silicon chips, to build a $12 billion factory in North Phoenix scheduled to open in 2024.

The cumulative impact of these STEM investments on Arizona's economy during the 10-year time period would be a gain of $44.2 billion in GDP, an increase of $28.0 billion in earnings, a rise of nearly $2.4 billion in tax payments, and an increase of 438,202 in total job years in Arizona, of which 410,923 (93.8 percent) would be private nonfarm jobs.

This scenario shows that it takes large investments to attract STEM jobs, since a $1 billion investment produces less than 8,500 STEM jobs in Arizona. To attract such large investments, investments in universities' STEM programs will be needed, as well as investments in economic development initiatives.

TABLE 29
ECONOMIC IMPACT OF PRIVATE-SECTOR INVESTMENT IN STEM ACTIVITIES OF $1 BILLION PER YEAR IN ARIZONA FROM 2021 THROUGH 2030

	Total Employment (Job Years)	Private Nonfarm Employment (Job Years)	Gross Domestic Product (Millions)	Earnings by Place of Work (Millions)	State and Local Government Tax Payments (Millions)
2021	8,463	8,159	$792.9	$512.0	$43.5
2022	16,984	16,232	1,559.8	1,017.6	86.5
2023	25,404	24,123	2,429.7	1,539.0	130.8
2024	33,606	31,757	3,260.9	2,064.3	175.5
2025	41,314	38,888	4,065.6	2,575.0	218.9
2026	48,698	45,695	4,858.8	3,076.6	261.5
2027	55,817	52,242	5,643.5	3,573.1	303.7
2028	62,601	58,462	6,404.9	4,055.3	344.7
2029	69,544	64,838	7,195.6	4,549.1	386.7
2030	75,772	70,528	7,932.3	5,001.6	425.1
10-Year Total	438,202	410,923	44,184.1	27,963.7	2,376.9

Sources: REMI, based on Emsi employment. The proportion of earnings paid in state and local government taxes is from the Institute on Taxation & Economic Policy, "Who Pays? A Distributional Analysis of the Tax Systems in All 50 States," October 2018, http://www.itep.org/whopays/. Definition of STEM-intensive industries produced by authors.

[27] https://azbigmedia.com/real-estate/taiwan-semiconductor-launches-38b-phoenix-presence-by-signing-major-lease/.

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APPENDIX A: STEM OCCUPATIONS

Emsi Occupation	Description
	COMPUTER CATEGORY
11-3021	Computer and Information Systems Managers
15-1211	Computer Systems Analysts
15-1212	Information Security Analysts
15-1221	Computer and Information Research Scientists
15-1231	Computer Network Support Specialists
15-1232	Computer User Support Specialists
15-1241	Computer Network Architects
15-1244	Network and Computer Systems Administrators
15-1245*	Database Administrators; and Database Architects
15-1251	Computer Programmers
15-1256**	Software Developers; and Software Quality Assurance Analysts and Testers
15-1257***	Web Developers; and Web and Digital Interface Designers
15-1299	Computer Occupations, All Other
	MATH CATEGORY
15-2011	Actuaries
15-2021	Mathematicians
15-2031	Operations Research Analysts
15-2041	Statisticians
15-2098****	Data Scientists; and Mathematical Science Occupations, All Other
	ENGINEERING CATEGORY
11-9041	Architectural and Engineering Managers
17-2011	Aerospace Engineers
17-2021	Agricultural Engineers
17-2031	Bioengineers and Biomedical Engineers
17-2041	Chemical Engineers
17-2051	Civil Engineers
17-2061	Computer Hardware Engineers
17-2071	Electrical Engineers
17-2072	Electronics Engineers, Except Computer
17-2081	Environmental Engineers
17-2111	Health and Safety Engineers, Except Mining Safety Engineers and Inspectors
17-2112	Industrial Engineers
17-2121	Marine Engineers and Naval Architects
17-2131	Materials Engineers
17-2141	Mechanical Engineers
17-2151	Mining and Geological Engineers, Including Mining Safety Engineers
17-2161	Nuclear Engineers
17-2171	Petroleum Engineers
17-2199	Engineers, All Other
	ENGINEERING TECHNICIAN CATEGORY
17-3011	Architectural and Civil Drafters
17-3012	Electrical and Electronics Drafters
17-3013	Mechanical Drafters
17-3019	Drafters, All Other
17-3021	Aerospace Engineering and Operations Technologists and Technicians
17-3022	Civil Engineering Technologists and Technicians
17-3023	Electrical and Electronic Engineering Technologists and Technicians
17-3024	Electro-Mechanical & Mechatronics Technologists and Technicians
17-3025	Environmental Engineering Technologists and Technicians
17-3026	Industrial Engineering Technologists and Technicians
17-3027	Mechanical Engineering Technologists and Technicians
17-3031	Surveying and Mapping Technicians
17-3098^	Calibration Technologists and Technicians; and Engineering Technologists and Technicians, Except Drafters, All Other

(continued)

APPENDIX A: STEM OCCUPATIONS (continued)

Emsi Occupation	Description
	SCIENCE CATEGORY
11-9121	Natural Sciences Managers
19-1011	Animal Scientists
19-1012	Food Scientists and Technologists
19-1013	Soil and Plant Scientists
19-1021	Biochemists and Biophysicists
19-1022	Microbiologists
19-1023	Zoologists and Wildlife Biologists
19-1029	Biological Scientists, All Other
19-1031	Conservation Scientists
19-1032	Foresters
19-1041	Epidemiologists
19-1042	Medical Scientists, Except Epidemiologists
19-1099	Life Scientists, All Other
19-2011	Astronomers
19-2012	Physicists
19-2021	Atmospheric and Space Scientists
19-2031	Chemists
19-2032	Materials Scientists
19-2041	Environmental Scientists and Specialists, Including Health
19-2042	Geoscientists, Except Hydrologists and Geographers
19-2043	Hydrologists
19-2099	Physical Scientists, All Other
	SCIENCE TECHNICIAN CATEGORY
19-4011^^	Agricultural Technicians; and Food Science Technicians
19-4021	Biological Technicians
19-4031	Chemical Technicians
19-4042	Environmental Science and Protection Technicians, Including Health
19-4045^^^	Geological Technicians; and Hydrologic Technicians
19-4051	Nuclear Technicians
19-4071	Forest and Conservation Technicians
19-4092	Forensic Science Technicians
19-4099	Life, Physical, and Social Science Technicians, All Other

* Combination of two Standard Occupational Classification (SOC) occupations: 15-1242 and 15-1243.
** Combination of two SOC occupations: 15-1252 and 15-1253.
*** Combination of two SOC occupations: 15-1254 and 15-1255.
**** Combination of two SOC occupations: 15-2051 and 15-2099.
^ Combination of two SOC occupations: 17-3028 and 17-3029.
^^ Combination of two SOC occupations: 19-4012 and 19-4013.
^^^ Combination of two SOC occupations: 19-4043 and 19-4044.

Sources: Emsi (occupational classification adapted from Executive Office of the President, Office of Management and Budget, "Standard Occupational Classification Manual," https://www.bls.gov/soc/2018/soc_2018_manual.pdf). Definition of STEM occupations produced by authors.

APPENDIX B: STEM INDUSTRIES

Emsi Industry	Description
	MANUFACTURING CATEGORY
325411	Medicinal and Botanical
325412	Pharmaceutical Preparation
325413	In-Vitro Diagnostic Substance
325414	Biological Product (except Diagnostic)
333242	Semiconductor Machinery
333314	Optical Instrument and Lens
333316	Photographic and Photocopying Equipment
334111	Electronic Computers
334112	Computer Storage Devices
334118	Computer Terminal and Other Computer Peripheral Equipment
334210	Telephone Apparatus
334220	Radio and Television Broadcasting and Wireless Communications Equipment
334290	Other Communications Equipment
334310	Audio and Video Equipment
334412	Bare Printed Circuit Boards
334413	Semiconductor and Related Devices
334416	Capacitor, Resistor, Coil, Transformer, and Other Inductors
334417	Electronic Connectors
334418	Printed Circuit Assembly (Electronic Assembly)
334419	Other Electronic Components
334510	Electromedical and Electrotherapeutic Apparatus
334511	Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instruments
334512	Automatic Environmental Controls for Residential, Commercial, and Appliance Use
334513	Instruments and Related Products for Measuring, Displaying and Controlling Industrial Process Variables
334514	Totalizing Fluid Meter and Counting Devices
334515	Instruments for Measuring and Testing Electricity and Electrical Signals
334516	Analytical Laboratory Instruments
334517	Irradiation Apparatus
334519	Other Measuring and Controlling Devices
334613	Blank Magnetic and Optical Recording Media
334614	Software and Other Prerecorded Compact Disc, Tape, and Record Reproducing
336411	Aircraft
336412	Aircraft Engines and Engine Parts
336413	Other Aircraft Parts and Auxiliary Equipment
336414	Guided Missiles and Space Vehicles
336415	Guided Missile and Space Vehicle Propulsion Units and Propulsion Unit Parts
336419	Other Guided Missile and Space Vehicle Parts and Auxiliary Equipment

(continued)

APPENDIX B: STEM INDUSTRIES (continued)

Emsi Industry	Description
	SERVICES CATEGORY
511210	Software Publishers
517312	Wireless Telecommunications Carriers (except Satellite)
517410	Satellite Telecommunications
517919	All Other Telecommunications
518210	Data Processing, Hosting, and Related Services
519130	Internet Publishing and Broadcasting and Web Search Portals
541330	Engineering Services
541340	Drafting Services
541360	Geophysical Surveying and Mapping Services
541370	Surveying and Mapping (except Geophysical) Services
541380	Testing Laboratories
541511	Custom Computer Programming Services
541512	Computer Systems Design Services
541513	Computer Facilities Management Services
541519	Other Computer Related Services
541620	Environmental Consulting Services
541690	Other Scientific and Technical Consulting Services
541713	Research and Development in Nanotechnology
541714	Research and Development in Biotechnology (except Nanotechnology)
541715	Research and Development in Other Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology)

Sources: Emsi (industrial classification adapted from Executive Office of the President, Office of Management and Budget, “North American Industry Classification System,” https://www.census.gov/eos/www/naics/). Definition of STEM-intensive industries produced by authors.

APPENDIX C: The REMI Model

The REMI model is a dynamic forecasting and analysis tool developed by Regional Economic Models Inc., recognized by the business and academic communities as a leading economic modeling tool. At once an input-output model, econometric model, and computable general equilibrium model, REMI contains a wealth of detail about industries and interindustry relationships. REMI PI+ V2.4.1 for Arizona was used for this report.

Through its dynamic modeling, REMI helps track the economic impact of a business, industry, or policy change at different points in time. The method used in this report for estimating economic impact involves four fundamental steps:

- Preparation of a baseline forecast for the state economy. This baseline scenario provides a forecast of the future path of the state's economy based on a combination of the extrapolation of historic economic conditions and an exogenous forecast of relevant national economic variables. This is often referred to as the "business as usual" case.
- Development of a policy scenario. This policy scenario describes the direct impacts that STEM operations or certain policies will generate in Arizona.
- Preparation of a forecast of the state economy based on the policy scenario. This alternative forecast provides a simulation of the future or alternative path of the Arizona regional economy, based on the above assumptions.
- Comparison of the baseline and policy scenario forecasts. The differentials between the future/alternative values of each variable in the forecast results provide numeric estimates of the nature and magnitude of impacts that STEM operations will have on the Arizona economy, relative to the baseline.

These impacts (contributions) include direct effects arising from direct jobs, and multiplier effects that arise when spending on payroll and general procurement ripples through the local economy. The presence or expansion of STEM operations directly affects the state economy through employment of STEM workers, and the payment of wages, salaries, and benefits to these workers. Multiplier effects arise through purchases of supplies and services from Arizona vendors, the upstream demands placed by those suppliers, and the expenditures of workers either directly or indirectly associated with STEM in the local economy.

The total impacts of STEM activities will be the final changes in the state's economy after all of the multiplier effects ("ripple effects") caused by the direct impacts have worked their way through the economy. In the end, the total changes in jobs and incomes are a multiple of the initial direct effects, and indicate how much larger the Arizona economy is because of the presence of STEM workers.

Impacts are reported in terms of the following measures:

- Total employment is the total number of jobs in Arizona, encompassing every sector and industry. Jobs over the years can be combined into "job years," a long-term measure of employment.
- Total private, nonfarm employment is the total number of jobs in the state excluding government and farm workers.
- Gross domestic product (GDP) represents new production, sometimes called "value added." More specifically, it is the dollar value of all goods and services produced for

final demand in the state. It excludes the value of intermediate goods and services purchased as inputs to final production.

- Earnings by place of work is the sum of wages and salaries, supplements to wages and salaries, and proprietors' income.

THE PRODUCTIVITY AND PROSPERITY PROJECT

The Productivity and Prosperity Project: An Analysis of Economic Competitiveness (P3) is an ongoing initiative begun in 2005, sponsored by Arizona State University President Michael M. Crow. P3 analyses incorporate literature reviews, existing empirical evidence, and economic and econometric analyses.

Enhancing productivity is the primary means of attaining economic prosperity. Productive individuals and businesses are the most competitive and prosperous. Competitive regions attract and retain these productive workers and businesses, resulting in strong economic growth and high standards of living. An overarching objective of P3's work is to examine competitiveness from the perspective of an individual, a business, a region, and a country.

THE CENTER FOR COMPETITIVENESS AND PROSPERITY RESEARCH

The Center for Competitiveness and Prosperity Research is a research unit of the L. William Seidman Research Institute in the W. P. Carey School of Business, specializing in applied economic and demographic research with a geographic emphasis on Arizona and the metropolitan Phoenix area. The Center conducts research projects under sponsorship of private businesses, nonprofit organizations, government entities and other ASU units. In particular, the Center administers both the Productivity and Prosperity Project, and the Office of the University Economist.

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