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Innovative Job Growth In the 21st Century: Has the Tech-Ecommerce Ecosystem Become the New Manufacturing?

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INTRODUCTION

For most of the 20th century, manufacturing was the paradigmatic industry for generating jobs through innovation. Industrial giants such as General Motors, General Electric, Eastman Kodak, IBM, and DuPont were renowned global technology leaders, blazing new trails in areas ranging from lighting and X-ray machines, to photographic film and computers, to synthetic materials such as nylon and Teflon and commercial jet engines.

Technological innovation, in turn, enabled these pioneering companies to become potent sources of good-paying jobs for U.S. workers. Collectively they employed millions of Americans, collaborating with smaller suppliers to form overlapping industrial ecosystems that supported communities in rural and urban areas across the country. Kodak was the classic example, of course, with the company's powerhouse position in photography fueling the rise of its headquarters and main manufacturing center in Rochester (NY).

Manufacturing employment in the United States peaked in 1979. Since then, the sector has been a drag on job growth. Big companies have shrunk, consolidated, or disappeared. The once vibrant web of manufacturing suppliers has atrophied, with much of the supply chain now outside the country. And states where manufacturing once ruled have seen factory jobs dwindle, in some cases to almost nothing. In 1979, factory jobs accounted for more than one-third of the private workforce in 21 states, topped by South Carolina and North Carolina with fully 43% and 42% of their private employment in manufacturing. By 2019, those states were down to 15% and 13% of jobs, respectively, in manufacturing.

Instead, the mantle of global innovation leadership has shifted to America's tech-ecommerce ecosystem. And perhaps surprisingly, so has the role of job creator. As we see in the next section, the top five tech-ecommerce firms—Apple, Alphabet, Microsoft, Facebook, and Amazon—employed 1.8 million workers globally as of early 2021. By comparison, the top five industrial firms by stock market value in the peak manufacturing employment year of 1979—GM, GE, IBM, Kodak, and Dupont—had a total global employment of 1.9 million, just slightly more.[1]

By our calculations, the tech-ecommerce ecosystem—including both large and small employers—has arisen to become the top job creator in the U.S. economy. Based on data from the Bureau of Labor Statistics, the industries in the tech-ecommerce ecosystem (described below) generated more than 1.2 million net new jobs from 2016 to 2020, including the pandemic. The next biggest growth sector was healthcare and social assistance, with 700,000 net new jobs created.

Moreover, average pay in the tech-ecommerce ecosystem, even omitting the headquarter states of California and Washington, is 44% higher than average pay in the private sector, and 21% higher than average pay in manufacturing nationally. This calculation is based on looking across all roles and positions in the tech-ecommerce ecosystem, from fulfillment center and delivery workers to software developers and AI experts.

In this paper, we analyze the historical role of manufacturing in job creation in the twentieth century, going back to the founding of General Motors in 1909. Based on the metrics we calculate, we find that the tech-ecommerce ecosystem is as economically important to overall job growth today as manufacturing was during the postwar period.

Delving deeper into today's tech-ecommerce workforce, we find that the distribution of pay in the tech-ecommerce ecosystem is spread out far more evenly than in the manufacturing sector. Manufacturing jobs are heavily concentrated in occupational groups with average hourly pay of $20 or less, based on data from the BLS Occupational Employment Statistics program. By contrast, the tech-ecommerce sector has a relatively even distribution of low, middle, and high-paying jobs.

One concern is that tech-ecommerce jobs are excessively concentrated geographically in a few states, while manufacturing has historically been an important source of jobs over a wider area. In order to examine this issue, we developed three new tools to analyze the geographic impact of the tech-ecommerce ecosystem.

- First, the PPI Tech-Ecommerce-Manufacturing (TEM) Index compares tech-ecommerce and manufacturing jobs and pay for each state. The TEM Index gives states such as Colorado, Florida, and Georgia high marks because their tech-ecommerce ecosystem is sizable compared to state manufacturing, and those tech-ecommerce workers are paid more on average than manufacturing workers in those states.
- Second, the PPI Tech-Ecommerce Change (TEC) Index measures the pre-pandemic contribution of the growth of tech-ecommerce jobs by state. We compare net new jobs generated by the tech-ecommerce ecosystem in the 2007-2019 and 2016-2019

periods with total net new private sector jobs to calculate the index. States such as Mississippi, Illinois and Ohio ranked high on the TEC Index because tech-ecommerce job growth helped compensate for slow job growth in other parts of the state economy.

- Third, the PPI Tech-Ecommerce Resilience (TER) Index measures the ability of the tech-ecommerce ecosystem to cushion the economic blow from the pandemic. In virtually every state, private sector jobs fell from June 2019 to June 2020 while tech-ecommerce jobs rose. The index is calculated as the absolute value of net new tech-ecommerce jobs over this period, divided by the decline in private sector jobs. For example, Arizona was ranked number two by the index because of its large growth in tech-ecommerce jobs relative to the overall economy. Also high on the list were states such as Idaho, Utah, and Ohio.

We conclude with a brief consideration of the future of tech-ecommerce ecosystem jobs. Note that this paper draws on earlier PPI research, namely our 2017 papers, "An Analysis of Job and Wage Growth in the Tech/Telecom Sector," and "How Ecommerce Creates Jobs and Reduces Income Inequality."

HISTORICAL COMPARISON

We are all familiar with the great manufacturing giants of the past. Companies such as General Motors, General Electric, Eastman Kodak and IBM were justly revered for their job-creating ability. In 1979—the peak year for manufacturing employment in the U.S.—GM had a global workforce of 863,000; GE employed 405,000; and IBM had 373,000 workers. In total, the top 5 industrial firms by stock market value in 1979, including Kodak and Dupont, had a total employment of almost 1.9 million (Table 1).

By comparison, the top tech firms seemed reluctant to hire for most of their existence. When the iPhone came out in 2007, Apple had only 22,000 workers. At that time, Google and Amazon both employed around 17,000. Microsoft was the giant of the bunch with 79,000, which was still well below the level of the great industrial companies of the past.

Notably, in 2007 Facebook, which had not yet gone public, had less than 500 employees.[2] Journalists held up the young company—which by some measures was valued at $15 billion—as the epitome of the ability of technology to generate value without workers.[3]

The "jobless growth" narrative only intensified when Facebook bought Instagram in 2012 for $1 billion. At the time, Instagram, known for its photosharing capabilities, had only 13 employees.[4] That purchase prompted unflattering comparisons to photo giant Kodak, which had just gone bankrupt a few months earlier, weighed down by years of bad decisions. The era when an innovation-driven company like Kodak could prosper by creating hundreds of thousands of well-paying jobs seemed over.

But not so fast. As of February 2021, today's tech giants employ almost as many workers as the industrial giants of the past. The top five tech-ecommerce firms today have a total global employment of 1.8 million, based on the most recent fiscal year, and they continue to grow. Barring major catastrophe, they appear likely to pass the global employment level of the 1979 industrial giants next year. And while not all of these companies break out domestic from global employment, it appears that U.S. jobs at the tech-ecommerce leaders are roughly comparable to U.S. jobs at the top industrial giants in 1979.[5]

What's even more impressive is that the tech-ecommerce companies have reached that employment level much faster than the industrial giants did. Measured from the date of their IPO, the five top tech companies average 24 years old. By contrast, the five industrial giants averaged 76 years old in 1979, measuring from date of restructuring the company into its modern form.[6] In other words, the tech-ecommerce companies had roughly the same employment even though averaging one-third the age.

In addition, the tech-ecommerce leaders have grown to 100,000 workers faster than traditional industrial giants such as GE, IBM, Bethlehem Steel, and Kodak (Table 2). Google took 15 years to get to the 100,000 mark, and Amazon took 16 years. Meanwhile GE took 49 years, while Kodak took 63 years. Indeed, in this employment context industrial companies like GE and Kodak turn out to be employment laggards rather than leaders.

TABLE 1: TECH-ECOMMERCE JOBS IN HISTORICAL CONTEXT

TECH-ECOMMERCE LEADERS	EMPLOYMENT AS OF END MOST RECENT FISCAL YEAR, FEBRUARY 2021
Amazon	1,298,000
Microsoft	163,000
Apple	147,000
Google	135,301
Facebook	58, 604
Total global employment, latest fiscal years, February 2021	1,801,905
Total global employment, 5 top industrial companies by market value in 1979 (IBM, GM, GE, Kodak, DuPont)	1,855,619

Data: Progressive Policy Institute, corporate reports

TABLE 2: FAST-GROWING TECH FIRMS

	YEARS TO REACH 100,000 EMPLOYEES*
Google/Alphabet	15
Amazon	16
Walmart	16
General Motors	17
Microsoft	29
Apple	34
IBM	36
Bethlehem Steel	36
General Electric	49
Kodak	63

**Dated from IPO or corporate formation*
Data: Progressive Policy Institute, corporate reports

JOBS IN THE TECH-ECOMMERCE ECOSYSTEM

In the previous section, we have shown how employment at the tech-ecommerce leaders now matches the historical industrial giants. But the tech-ecommerce leaders don't exist in a vacuum: They are embedded in a broader ecosystem of large and small companies that are adding workers as well.

In this section, we use BLS statistics to identify the broader "tech-ecommerce ecosystem."[7] We show how the tech-ecommerce ecosystem has become the major source of net new jobs in the United States over the past four years—exceeding even health care. This is a new development, after many years where healthcare was the job leader.

The first step is identifying the key industries of the tech-ecommerce ecosystem. Note that the Bureau of Labor Statistics assigns employment to industries by establishment, not by firm. That means a large company like Amazon, with many establishments across the country, may have workers assigned to multiple industries.

Keeping that in mind, we can identify four key tech industries and three key ecommerce industries. The four tech industries are software publishing (NAICS 5112); data processing and hosting (NAICS 518); Internet publishing and search, and other information services (NAICS 519); and computer systems design and programming (NAICS 5415). The three ecommerce industries are electronic shopping and mail order houses (NAICS 4541); local delivery (NAICS 492); and ecommerce fulfillment and warehousing (NAICS 493).

TABLE 3: INDUSTRIES IN TECH-ECOMMERCE ECOSYSTEM

		CHANGE IN THOUSANDS OF JOBS		
NAICS CODE	INDUSTRY	2016-20	2016-2019	2019-2020
4541	Electronic shopping and mail order houses	52	31	21
492	Local delivery	312	182	130
493	Ecommerce fulfillment centers and warehousing	412	297	115
5112	Software publishing	140	107	33
518	Data processing and hosting	52	39	13
519	Internet publishing and search, and other information services	92	75	17
5415	Computer systems design and programming	195	201	-7
Total	Tech-ecommerce ecosystem	**1255**	**933**	**322**
	REST OF PRIVATE SECTOR	2016-20	2016-2019	2019-2020
	Health and social assistance	707	1352	-645
	Construction	541	765	-224
	Financial activities	437	467	-30
	Professional and technical (except computer)	350	454	-103
	All other industries	-5119	2210	-7328

Data: PPI, BLS QCEW

Table 3 lays out our analysis for three time periods: 2016 to 2020, 2016 to 2019, and the pandemic year 2019 to 2020. The first striking point is that the annual job growth for the tech-ecommerce ecosystem in the pre-pandemic years (311,000 annually) is virtually identical to the pandemic year (322,000). In other words, tech-ecommerce jobs turned out to be resilient to the pandemic, a point that we will discuss later in this paper on the state level.

The second point is that the tech-ecommerce ecosystem added more than 1.2 million jobs in the four years between 2016 and 2020, by far the largest source of jobs in the economy. The closest competitor was healthcare and social assistance, with 700,000 jobs added. This is likely the first time over any recent period that tech-ecommerce job growth has beaten health care jobs growth.

Now we come to the caveats for this analysis. First, as noted above, the Bureau of Labor Statistics categorizes employment by establishment, not by firm. So, the jobs at a standalone ecommerce fulfillment center run by a large brick-and-mortar retailer might very well be assigned to NAICS 493, even if most of the retailer's remaining store salesclerks are assigned to the retail trade sector.

Second, the BLS treats the industry assignment of a particular establishment as confidential. So there typically is no way of knowing, for example, whether a research facility doing programming work on autonomous vehicles is assigned to the auto industry or to the custom computer programming industry.

Third, we could have expanded the set of tech industries to include semiconductors, computers and communications equipment manufacturing; computer and software wholesalers; and business-to-business electronic markets. But at least for this time period, none of these industries would have changed our results at all.

COMPARISON TO MANUFACTURING

How does tech-ecommerce growth in recent years stack up historically against manufacturing? General Motors, the biggest industrial firm by employment for most of the 20th century, was founded in 1909, and manufacturing employment peaked in 1979. It's natural to break that seventy-year stretch into two periods. The first forty years, 1909-1949, includes the big manufacturing expansion of the early 20th century, the Great Depression, and World War II. The next thirty years, 1949-1979, includes the post-war boom.

The top panel of Table 4 shows the average annual number of jobs created by the manufacturing sector in these periods, as well as its share of overall private sector nonfarm job creation. In the 1909-1949 period, manufacturing accounted for a stunning 37% of private nonfarm job growth. In the 1949-1979 period, manufacturing was still an important source of jobs, generating about 200,000 net new jobs per year. That accounted for about 17% of private sector job creation.

How does that compare to the importance of tech-ecommerce job creation? Let's consider first the business cycle that started in 2007 and ended in 2019, as shown in the second panel of Table 4. Over that period, tech-ecommerce job growth accounted for about 18% of private sector job growth, comparable to the postwar manufacturing performance.

One caveat is that this analysis does not take into account the potential impact of spillover effects, since post-war manufacturers had a very deep web of local suppliers. But at least in terms of raw numbers, it's reasonable to say that the tech-ecommerce ecosystem is as economically important to overall job growth today as manufacturing was during the postwar period.

Pay

How much do tech-ecommerce workers get paid, and how does that compare to manufacturing? Based on BLS QCEW data, we calculate that as of 2019 the average wages and salaries in the tech-ecommerce ecosystem was $101,500 per worker, compared to $59,200 for the private sector and $69,900 for manufacturing (Table 5). These amounts include most exercised stock options, vested restricted stock units, and other bonus pay. They are not adjusted for hours of work.

Since the tech-ecommerce leaders are mostly headquartered in California and Washington, we remove those states to get a more "typical" figure for tech-ecommerce pay of $84,900, or 44% higher than the average pay in the private sector.

Average pay per worker in the tech-ecommerce ecosystem, excepting California and Washington, is 21% higher than average pay in manufacturing. In other words, when we look across the whole universe of tech-ecommerce jobs, from fulfillment center workers to software developers, their average pay is 21% higher than the average pay looking across the whole universe of manufacturing jobs, from engineers to executives to production workers.

In part, this difference in pay is related to differences in education levels. As shown in Table 6, workers in the tech-ecommerce ecosystem have a higher education level, on average, than workers in manufacturing. For example, 43% of manufacturing workers in 2019 had at most a high school diploma and no college education, compared with all 20% of tech-ecommerce workers.[8] Similarly, the tech-ecommerce workforce is much more likely to have college degrees.

But even when we compare workers with equal education levels, a preliminary analysis suggests that the tech-ecommerce workforce gets paid as much or more as manufacturing workers. For example, as of March 2019, workers with an associate degree or some college get paid 6% more, on average, in the tech-ecommerce ecosystem compared to manufacturing. Workers with just a bachelor's degree get paid an average of 14% more in the tech-ecommerce ecosystem (this is a preliminary analysis because we have not adjusted for geography or for experience). These results are reported in Table 7.

TABLE 4: MANUFACTURING VERSUS TECH-ECOMMERCE JOB GROWTH

	AVERAGE ANNUAL MANUFACTURING JOB GROWTH (THOUSANDS)	SHARE OF PRIVATE SECTOR NONFARM JOB GROWTH
1909-1949	170	37%
1949-1979	205	17%

	AVERAGE ANNUAL TECH-ECOMMERCE JOB GROWTH (THOUSANDS)	SHARE OF PRIVATE SECTOR NONFARM JOB GROWTH
2007-2019	189	18%
2016-2019	311	15%

Data: PPI, BLS

TABLE 5: TECH-ECOMMERCE PAY, 2019

	ANNUAL WAGES AND SALARIES, THOUSANDS OF DOLLARS*
Tech-ecommerce	101.5
Tech-ecommerce**	84.9
Private sector	59.2
Manufacturing	69.9

**including exercised stock options and vested restricted stock units*
***excepting California and Washington*
Data: Bureau of Labor Statistics QCEW

TABLE 6: EDUCATIONAL ATTAINMENT OF WORKERS, MANUFACTURING VS TECH-ECOMMERCE, 2019 (SHARE OF WORKFORCE)

	HIGH SCHOOL DIPLOMA OR LESS	ASSOCIATE DEGREE OR SOME COLLEGE	BACHELOR'S DEGREE ONLY	MORE THAN BACHELOR'S DEGREE
Manufacturing	42.6%	26.5%	21.9%	9.0%
Tech-ecommerce	20.1%	21.9%	38.9%	19.1%
All workers	33.3%	27.5%	24.9%	14.3%

Data: PPI, BLS 2019 March ASEC supplement to CPS

TABLE 7: EARNINGS BY EDUCATION LEVEL (AVERAGE ANNUAL EARNINGS, THOUSANDS OF DOLLARS)

	HIGH SCHOOL DIPLOMA	ASSOCIATE DEGREE OR SOME COLLEGE	BACHELOR'S DEGREE ONLY
Manufacturing	45.5	54.9	89.1
Tech-ecommerce	46.5	58.1	102.0
Premium	2.1%	5.8%	14.4%

Data: PPI, 2019 March ASEC supplement to CPS

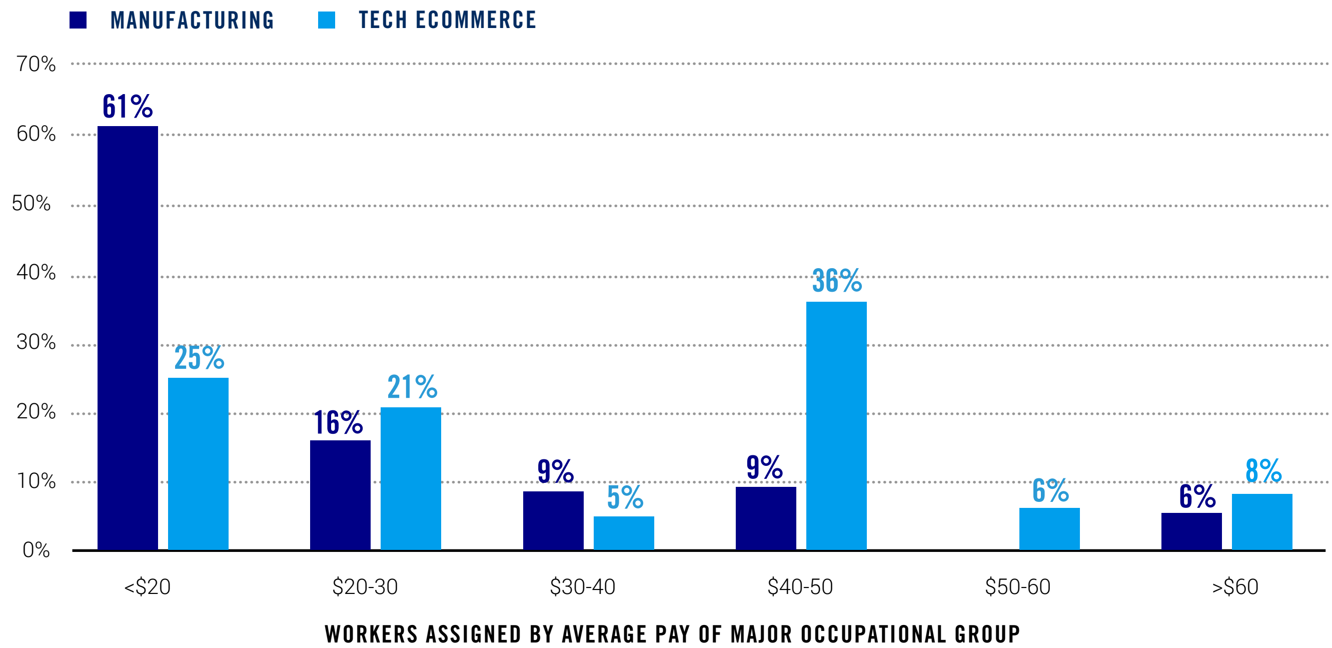
Distribution of earnings

Usually, policymakers have this vision of manufacturing as a rare-remaining haven of middle-class jobs. Tech-ecommerce jobs, by contrast, are commonly thought of as a barbell with a group of billionaires and highly paid coders at one end and a mass of low-paid workers at the other.

But reality is very different. Manufacturing, at least these days, is heavily weighted towards low-end workers. Based on BLS Occupational Employment Statistics (OES) data, 77% of manufacturing workers are in occupational groups with a mean hourly wage of $30 or less.[9] More than 60% of manufacturing workers are in occupational groups with a mean hourly wage of $20 or less. As we can see in Figure 1, the earnings distribution for manufacturing is skewed heavily to the left.

The earnings distribution for tech-ecommerce jobs, by contrast, is much more even, including both low-pay jobs and what looks like a group of upper middle-class positions. If we look more closely, the rapidly growing computer systems design industry has a large number of well-paid positions for workers with at least a high school diploma, but less than a bachelor's degree, earning an average of $80,000 per year or so. Measured by education level, similar workers in the auto industry only earn $50,000 per year.

FIGURE 1. MANUFACTURING VS TECH-ECOMMERCE HOURLY PAY DISTRIBUTION (SHARE OF WORKFORCE, ASSIGNED BY MAJOR OCCUPATIONAL GROUP)



Data: BLS, OES

Demographic Comparison

Given the growing importance of tech-ecommerce jobs, it's worthwhile to delve further into who is getting these jobs. In particular, we can use the Current Population Survey (CPS) to compare employment of women, black workers, and Hispanic workers in the tech-ecommerce ecosystem with employment of these groups in the manufacturing sector.

Let's start by considering black workers as a percentage of the tech-ecommerce workforce. We calculated total 2020 employment of workers who identify as black in the tech-ecommerce industries, and divided by total employment in the ecosystem, based on CPS data.[10] We then do the same for manufacturing.

We found that in 2020, black workers comprised 13.5% of the tech-ecommerce ecosystem workers. By comparison, black workers were only 10.3% of the manufacturing workforce, a substantial difference of more than three percentage points. So black workers make up a bigger share of the tech-ecommerce workforce than they do in manufacturing (Figure 2).

This gap has widened over time. In 2016, for example, black and African-American workers made up 12.7% of the tech-ecommerce ecosystem workforce, and 10% of the manufacturing workforce, according to CPS data, a difference of 2.7 percentage points.

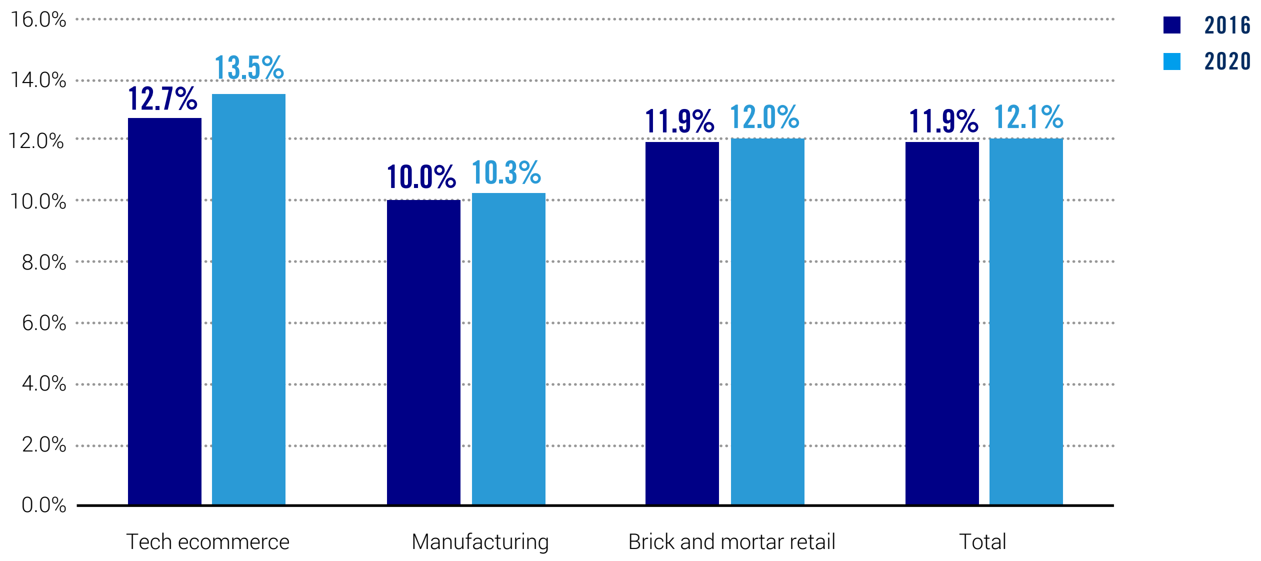
It's worth doing a couple of other comparisons as well. First, the low share of blacks in manufacturing is not new. BLS data from 1995 shows that 10.4% of the manufacturing workforce was comprised of black and African-American workers 25 years ago.[11] Going further back to 1965, only 8.3 percent of manufacturing workers were non-white, compared to 11 percent for the nonagricultural workforce as a whole.[12] Black workers have been underrepresented in manufacturing for many years compared to the overall workforce.

By contrast, black workers are over-represented in the tech-ecommerce ecosystem (13.5% in 2020) compared to their share in the economy as a whole (12.1%), or for brick-and-mortar retail (12.0%). The implication is that the rapid growth of ecommerce jobs is actually a plus for black workers compared to brick-and-mortar retail.

Next we look at the importance of women in the tech-ecommerce ecosystem workforce. Women have been underrepresented in tech for years, and our data is consistent with that. We find 31.5% of tech-ecommerce ecosystem workers are women in 2020, up from 30% in 2016. That's clearly lower than the 46.8% for the economy as a whole. However, only 29.5% of manufacturing workers are women, making the manufacturing sector even more unrepresentative (Figure 3).

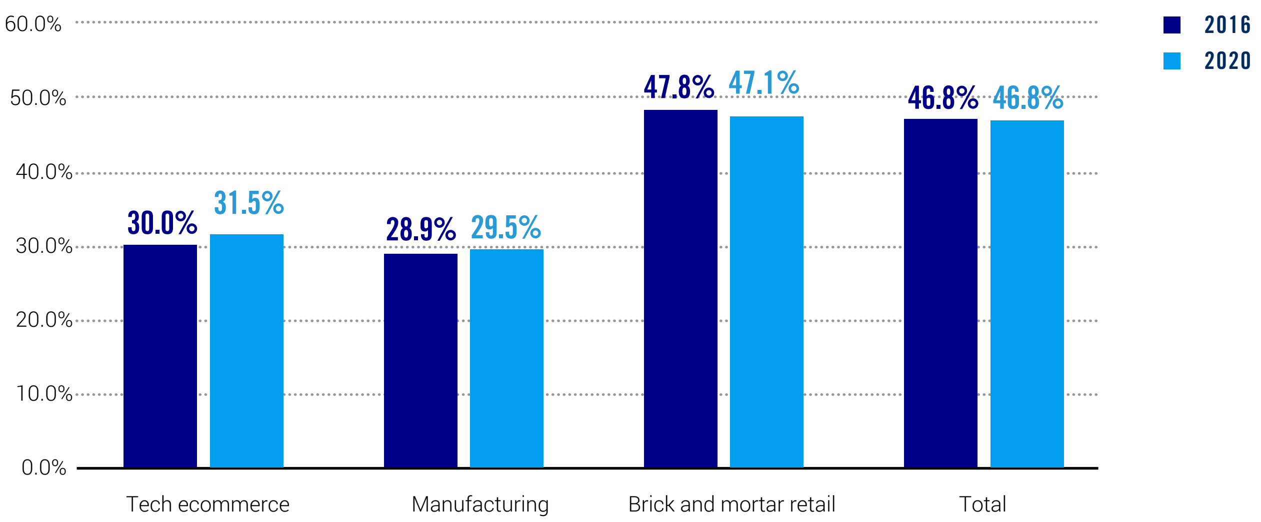
Next we come to the role of Hispanic and Latino workers in the tech-ecommerce ecosystem (Figure 4). Here there is good news and bad news. The good news is that the number of Hispanics and Latinos in tech-ecommerce rose by 76% from 2016 to 2020, getting to roughly 1 million workers. As a result, the share of Hispanic and Latino workers in tech-ecommerce rose as well, going from 11% in 2016 to 13.7% in 2020. The bad news is that tech-ecommerce still has a lower share of Hispanic and Latino workers than manufacturing, brick-and-mortar retail, and the economy as a whole.

FIGURE 2. BLACK WORKERS AS SHARE OF WORKFORCE, 2016 AND 2020



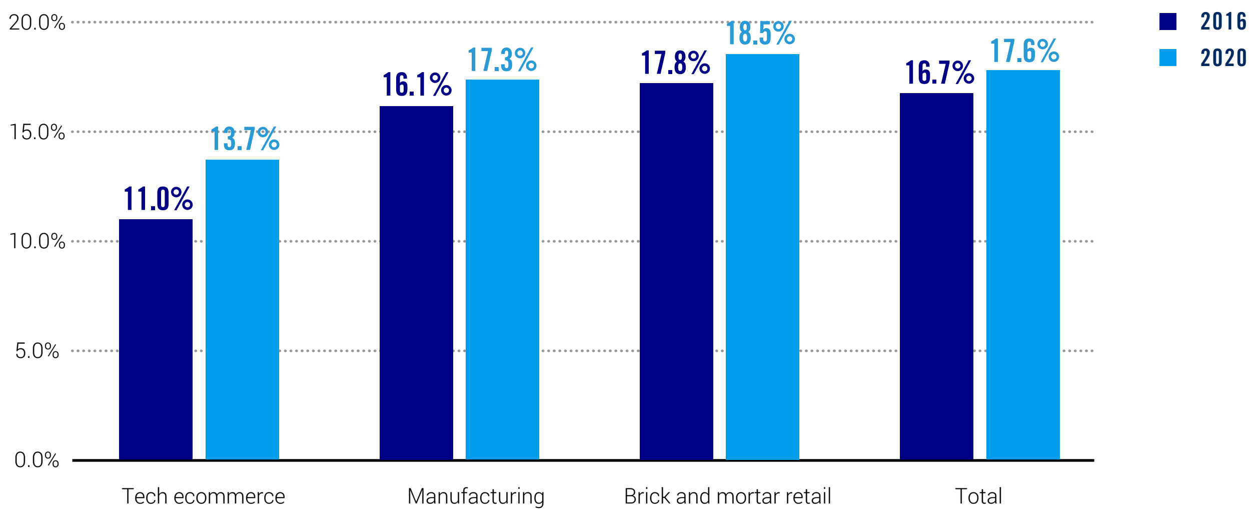
Data: PPI, BLS, CPS

FIGURE 3. FEMALE WORKERS AS SHARE OF WORKFORCE, 2016 AND 2020



Data: PPI, BLS, CPS

FIGURE 4. LATINO WORKERS AS SHARE OF WORKFORCE, 2016 AND 2020



Data: PPI, BLS, CPS

THE PPI TECH-ECOMMERCE-MANUFACTURING (TEM) INDEX

In their heyday, manufacturing jobs were well known for being widely distributed across the country. A small town might have its local factory, which supplied jobs for the town's graduates. Indeed, most states had sizable manufacturing industries. As we noted in the introduction, manufacturing was more than one-third of the private sector workforce in 21 states in 1979.[13]

Obviously the tech-ecommerce ecosystem can't reproduce the geographic footprint of manufacturing from forty years ago—at least not yet. A better question to ask is how the geographical distribution of tech-ecommerce jobs compares to the current distribution of manufacturing jobs.

There are two dimensions to geographic distribution: Quantity and pay. So in addition to comparing the quantity of manufacturing jobs to the quantity of tech-ecommerce jobs on a state-by-state level, we take into account the generally higher pay level for most tech-ecommerce jobs. The result is the PPI Tech-Ecommerce-Manufacturing (TEM) Index.

To get the TEM Index, we first start by calculating the "job ratio"—the ratio of number of tech-ecommerce jobs in a state to the number of manufacturing jobs. Then we calculate the "pay ratio"—the ratio of tech-ecommerce average pay to manufacturing average pay in a state.[14] Then we average the job ratio and the pay ratio to get the TEM Index.

For example, in Georgia in 2019, the number of tech-ecommerce jobs totaled 203,500, compared to 404,100 manufacturing jobs, for a "job ratio" of roughly 0.50 (Table 8). So, if we just looked at quantity of jobs, the economic impact of the tech-ecommerce ecosystem is substantially less than manufacturing.

But pay matters too. In Georgia, the average pay in the tech-ecommerce ecosystem was $79,100 in 2019, compared to $58,200 for manufacturing, looking across all skill levels in both cases. The "pay ratio," which is tech-ecommerce pay divided by manufacturing pay, comes to 1.36. So, pay in the tech-ecommerce ecosystem is 36% higher than in manufacturing, looking across all positions and skill levels. That gives each individual job in the tech-ecommerce ecosystem a bigger economic impact than each individual job in manufacturing.

The TEM Index for a state is calculated by averaging the job ratio and the pay ratio. For Georgia, the index is 0.93, which puts the state 12th on the list.

Table 6 shows the TEM index for all 50 states. The median job ratio is 0.35, which means in the typical state tech-ecommerce jobs are approximately one-third that of manufacturing jobs. The median pay ratio is 1.18, which means in the typical state the average tech-ecommerce pay is 18% higher than the average manufacturing pay.

We note that the pay ratio is less than one in only nine states. That means for the most part, most Americans live in states where the tech-ecommerce ecosystem pays better than manufacturing. Remember that the tech-ecommerce pay figure includes all positions and skill levels, from fulfillment center and delivery workers to website designers.

Note that the BLS reports sufficient data to calculate the job ratio and the pay ratio for many counties. Consider, for example, Davidson County, Tennessee, which contains the city of Nashville. Nashville will be the site of an Amazon office complex, now being built. But even before then, tech-ecommerce jobs were growing in the county. Based on BLS data, Davidson County included 19,000 tech-ecommerce jobs in 2019, up 30 percent since 2016. The average annual tech-ecommerce pay in Davidson County was $71,000 in 2019, up 12 percent since 2016.

By contrast, the BLS reports that the average annual manufacturing pay in Davidson County was $58,000 in 2019, with roughly 20,000 manufacturing workers in the country. Both manufacturing employment and pay showed very little change between 2016 and 2019.

So in 2019 the pay ratio in Davidson County was 1.22, showing that tech-ecommerce pay was 22% above manufacturing pay. It's worth noting that judging by want ads, entry-level manufacturing wages in Davidson County as of early 2021 appeared to be on the order of $15-$17 per hour. For example, the county included manufacturers such as Moeller Precision Tools, which in March 2021 was advertising for an entry level machinist job at $15-16 per hour; Tachi-S Automotive Seating, which was advertising for an assembly line worker at pay starting at $16.50 per hour; and Hayward Industries, a publicly traded manufacturer of pool equipment, which was advertising for manufacturing associates at $15-17 per hour.

TABLE 8: PPI TECH-ECOMMERCE-MANUFACTURING INDEX (TEM), 2019

		THOUSANDS OF JOBS			THOUSANDS OF DOLLARS (AVERAGE)			
	STATE	TECH-ECOMMERCE	MANUF.	JOB RATIO*	TECH-ECOMMERCE PAY	MANUF. PAY	PAY RATIO**	TEM INDEX***
1	Washington	256.7	290.3	0.88	185.5	81.2	2.28	1.58
2	Virginia	247.7	242.2	1.02	107.7	61.3	1.76	1.39
3	New York	312.1	437.0	0.71	120.5	69.2	1.74	1.23
4	Maryland	133.9	112.3	1.19	96.0	79.0	1.22	1.20
5	California	927.0	1322.5	0.70	160.8	98.2	1.64	1.17
6	Colorado	129.4	150.1	0.86	106.6	73.9	1.44	1.15
7	Massachusetts	181.7	244.3	0.74	139.4	89.7	1.55	1.15
8	Alaska	4.6	13.1	0.35	102.0	52.7	1.93	1.14
9	Hawaii	8.9	14.0	0.63	71.7	46.5	1.54	1.09
10	Utah	83.8	136.1	0.62	80.0	59.4	1.35	0.98
11	Florida	280.7	384.0	0.73	77.0	63.9	1.21	0.97
12	Georgia	203.5	404.1	0.50	79.1	58.2	1.36	0.93
13	New Jersey	199.8	249.5	0.80	84.2	81.6	1.03	0.92
14	Nevada	50.1	59.3	0.85	58.5	59.5	0.98	0.91
15	Montana	8.7	21.0	0.42	70.8	51.7	1.37	0.89
16	New Hampshire	26.6	71.5	0.37	102.3	73.0	1.40	0.89
17	North Carolina	151.5	477.1	0.32	83.1	61.1	1.36	0.84
18	Missouri	98.4	277.1	0.35	79.0	59.8	1.32	0.84
19	Rhode Island	13.4	39.7	0.34	80.5	60.3	1.33	0.84
20	Nebraska	32.3	99.9	0.32	70.9	52.7	1.34	0.83
21	North Dakota	7.9	26.5	0.30	72.9	55.2	1.32	0.81
22	Texas	453.1	906.0	0.50	87.4	79.8	1.10	0.80
23	New Mexico	12.3	28.5	0.43	64.5	55.7	1.16	0.79
24	Minnesota	87.5	324.0	0.27	89.5	68.1	1.31	0.79
25	Vermont	9.4	30.1	0.31	76.6	60.8	1.26	0.79

		THOUSANDS OF JOBS			THOUSANDS OF DOLLARS (AVERAGE)			
	STATE	TECH-ECOMMERCE	MANUF.	JOB RATIO*	TECH-ECOMMERCE PAY	MANUF. PAY	PAY RATIO**	TEM INDEX***
26	Arizona	112.9	177.6	0.64	73.1	79.0	0.93	0.78
27	Delaware	13.9	27.3	0.51	69.3	66.2	1.05	0.78
28	Illinois	226.8	585.9	0.39	84.8	72.8	1.16	0.78
29	Pennsylvania	247.7	574.8	0.43	71.8	64.2	1.12	0.77
30	Oregon	67.4	197.6	0.34	83.9	71.4	1.17	0.76
31	Tennessee	122.9	355.0	0.35	69.2	60.3	1.15	0.75
32	Connecticut	60.6	161.9	0.37	90.4	85.0	1.06	0.72
33	Maine	15.5	53.0	0.29	65.0	57.2	1.14	0.71
34	South Dakota	6.5	45.0	0.14	63.7	50.2	1.27	0.71
35	Wisconsin	94.8	483.2	0.20	71.7	59.1	1.21	0.70
36	Arkansas	27.4	162.2	0.17	60.0	49.2	1.22	0.69
37	Alabama	53.4	268.9	0.20	69.1	58.5	1.18	0.69
38	Michigan	117.4	625.7	0.19	79.2	68.5	1.16	0.67
39	Kansas	48.1	167.2	0.29	62.7	59.7	1.05	0.67
40	Idaho	15.4	68.4	0.23	68.9	62.5	1.10	0.66
41	Ohio	197.6	700.8	0.28	65.1	62.9	1.03	0.66
42	Kentucky	87.9	252.6	0.35	59.1	61.2	0.97	0.66
43	Wyoming	4.3	10.0	0.42	58.8	68.7	0.86	0.64
44	South Carolina	60.0	258.3	0.23	62.6	60.9	1.03	0.63
45	Iowa	40.0	226.2	0.18	62.2	60.2	1.03	0.60
46	West Virginia	13.8	47.0	0.29	53.4	61.1	0.87	0.58
47	Mississippi	28.8	146.8	0.20	47.5	50.1	0.95	0.57
48	Indiana	110.2	541.1	0.20	57.9	63.3	0.91	0.56
49	Oklahoma	35.0	140.8	0.25	51.3	60.0	0.86	0.55
50	Louisiana	33.3	137.7	0.24	58.5	77.6	0.75	0.50

District of Columbia omitted because too few manufacturing jobs
**Job ratio equals tech-ecommerce jobs divided by manufacturing jobs*
***Pay ratio equals average tech-ecommerce pay divided by manufacturing pay*
****PPI Tech-ecommerce-manufacturing Index equals average of job ratio and pay ratio for that state.*
Data: PPI, BLS

PPI TECH-ECOMMERCE-CHANGE (TEC) INDEX

The TEM Index described in the previous section is useful for taking a static picture of the tech-ecommerce ecosystem. But dynamics and rapid growth are important as well. This section will consider tech-ecommerce job growth over two periods, 2016-2019 and 2007-2019. The latter encompasses the entire previous business cycle.

As Table 9 shows, the state with the biggest growth in tech-ecommerce jobs is, not surprisingly, California. California added 208,000 tech-ecommerce jobs between 2016-2019, and 475,000 between 2007 and 2019. The second biggest state for tech-ecommerce job growth is Texas.

But California and Texas are also the biggest states, in absolute terms, meaning that the large number of net new tech-ecommerce jobs may simply reflect the size of the state. To get a better sense of the importance of tech-commerce growth on a state level, we compare it to the increase in private sector jobs over the same periods. We calculate the tech-ecommerce share of private sector job growth from 2007 to 2019, and from 2016 to 2019. Then we take the geometric average of the two shares to give us what we call the PPI Tech-Ecommerce Change (TEC) Index.

For example, the top-ranked state, Mississippi, has been dependent on growth in tech-ecommerce jobs to offset job losses in sectors that never recovered fully from the 2008-2009 recession, including construction, manufacturing, wholesale trade, retail trade, finance and insurance, professional services, and even hospitals. With total wage and salary payments of $1.4 billion in 2019, the tech-ecommerce ecosystem is playing an increasingly key role in the state's economy.

Or consider Ohio, which has been hard hit by weakness in manufacturing. The tech-ecommerce ecosystem generated 31,000 and 55,000 net new jobs in 2016-2019 and 2007-2019, respectively, accounting for 29% and 35% of private sector job growth. As a result, Ohio ranked number seven according to the Tech-Ecommerce Change Index. It should be noted that in the 2016-2019 period, net new tech-ecommerce jobs in Ohio exceeded net new private healthcare and social assistance jobs (roughly 24,000).

TABLE 9: PPI TECH-ECOMMERCE CHANGE (TEC) INDEX

		CHANGE IN TECH-ECOMMERCE JOBS, THOUSANDS		CHANGE IN TECH-ECOMMERCE JOBS AS SHARE OF CHANGE IN PRIVATE SECTOR JOBS		TECH-ECOMMERCE CHANGE INDEX*
	STATE	2016-2019	2007-2019	2016-2019	2007-2019	
1	Mississippi	4.8	11.2	38%	330%	1.11
2	Connecticut	4.5	11.7	43%	177%	0.88
3	Kansas	6.0	19.4	33%	55%	0.43
4	Illinois	34.1	79.4	34%	51%	0.42
5	Maryland	20.3	43.8	31%	36%	0.33
6	Vermont	0.7	2.1	29%	36%	0.33
7	Ohio	30.8	54.6	29%	35%	0.32
8	New Jersey	32.2	63.6	25%	40%	0.31
9	Washington	60.9	142.9	30%	31%	0.31
10	Kentucky	10.3	29.4	26%	28%	0.27
11	Alabama	8.2	17.1	12%	56%	0.26
12	Louisiana	7.1	10.1	53%	12%	0.25
13	California	208.4	475.1	25%	25%	0.25
14	Missouri	12.0	30.4	20%	29%	0.24
15	Iowa	3.9	8.0	40%	13%	0.23
16	New Hampshire	3.8	8.8	22%	24%	0.23
17	West Virginia	1.6	4.5	23%	NA	0.23
18	Indiana	13.8	51.0	15%	28%	0.21
19	Virginia	21.1	59.8	16%	27%	0.21
20	Pennsylvania	28.1	80.0	15%	26%	0.20
21	Oklahoma	7.2	16.7	16%	21%	0.19
22	Wisconsin	7.6	26.8	13%	25%	0.18
23	Massachusetts	22.1	69.5	16%	18%	0.17
24	Georgia	37.6	82.9	16%	18%	0.17
25	Michigan	17.3	36.2	17%	16%	0.16

		CHANGE IN TECH-ECOMMERCE JOBS, THOUSANDS		CHANGE IN TECH-ECOMMERCE JOBS AS SHARE OF CHANGE IN PRIVATE SECTOR JOBS		TECH-ECOMMERCE CHANGE INDEX*
	STATE	2016-2019	2007-2019	2016-2019	2007-2019	
26	Arizona	25.9	57.3	12%	22%	0.16
27	Nevada	14.5	24.6	12%	21%	0.16
28	Tennessee	17.7	49.1	13%	18%	0.15
29	District of Columbia	3.8	12.3	17%	14%	0.15
30	Colorado	25.5	50.3	16%	13%	0.15
31	Utah	14.5	40.3	12%	16%	0.14
32	New York	49.1	126.9	14%	13%	0.14
33	Nebraska	2.8	5.1	20%	9%	0.13
34	North Carolina	20.7	64.9	9%	16%	0.12
35	Florida	64.3	114.3	12%	12%	0.12
36	Rhode Island	-0.9	0.8	NA	12%	0.12
37	South Carolina	10.5	30.3	9%	14%	0.11
38	Oregon	13.4	24.3	11%	11%	0.11
39	Texas	89.7	214.8	12%	10%	0.11
40	Minnesota	7.5	20.8	10%	10%	0.10
41	Arkansas	2.2	4.9	8%	11%	0.09
42	New Mexico	1.8	2.8	6%	13%	0.09
43	South Dakota	0.9	2.0	11%	6%	0.08
44	Idaho	3.8	6.6	6%	8%	0.07
45	Montana	0.7	2.8	4%	9%	0.06
46	Alaska	0.4	0.8	NA	5%	0.05
47	Hawaii	0.9	0.8	8%	3%	0.04
48	Wyoming	0.3	0.0	30%	31%	0.04
49	Delaware	0.0	5.0	0%	20%	0.03
50	Maine	1.1	0.2	7%	1%	0.02
51	North Dakota	0.2	0.6	3%	1%	0.01

NA if either numerator or denominator is negative.
**Geometric average of tech-ecommerce shares for 2016-2019 and 2007-2019.*
Data: PPI, BLS

PPI TECH-ECOMMERCE RESILIENCE (TER) INDEX

The previous section covered the pre-pandemic period from 2016 to 2019. But initial data through June 2020 shows that in many states, the tech-ecommerce ecosystem helped buffer the local labor market against the Covid-19 recession (as the data becomes available, we will update these figures to include the third quarter).

From June 2019 to June 2020, private sector jobs fell in every state. That includes industries that are typically recession-resistant, such as healthcare and social assistance, where employment fell in all but one state.

Meanwhile, tech-ecommerce jobs rose in all but four states, as Table 10 shows. The biggest gains, as might be expected, were in California and Texas. But the raw numbers do not give the full impact. Instead, we compare the size of the tech-ecommerce gains with the size of the private sector job losses. We'll call the absolute value of that ratio the PPI Tech-Ecommerce Resilience Index. Table 10 provides the list of states, ranked by the index.

Consider Arizona, which is ranked number two on the Tech-Ecommerce Resilience Index. Between the second quarter of 2019 and second quarter of 2020 the number of tech-ecommerce jobs in Arizona rose by 15,000 jobs, driven mainly by warehousing jobs and software publishing. These gains did not fully eliminate the downward thrust of the COVID-19 recession, but they significantly cushioned the blows.

TABLE 10. PPI TECH-ECOMMERCE RESILIENCE (TER) INDEX, JUNE 2019-JUNE 2020

	STATE	CHANGE IN TECH-ECOMMERCE JOBS, THOUSANDS	TECH-ECOMMERCE RESILIENCE INDEX*
1	Idaho	1.7	0.16
2	Arizona	15.1	0.14
3	Utah	4.5	0.12
4	Washington	25.0	0.10
5	Oklahoma	7.6	0.09
6	Indiana	14.8	0.07
7	Ohio	26.9	0.07
8	Texas	48.7	0.07
9	Colorado	11.6	0.06
10	Kansas	4.7	0.06
11	Kentucky	7.9	0.06
12	Oregon	9.6	0.06
13	Connecticut	9.7	0.05
14	North Carolina	14.0	0.05
15	Maryland	13.6	0.05
16	Tennessee	8.6	0.05
17	Missouri	8.4	0.05
18	California	70.6	0.04
19	Virginia	13.2	0.04
20	Georgia	12.2	0.04
21	Florida	22.2	0.04
22	Delaware	1.4	0.04
23	Mississippi	2.0	0.03
24	Nebraska	1.5	0.03
25	Nevada	6.2	0.03
26	New Hampshire	1.8	0.03
27	New Jersey	15.8	0.03

	STATE	CHANGE IN TECH-ECOMMERCE JOBS, THOUSANDS	TECH-ECOMMERCE RESILIENCE INDEX*
28	Illinois	16.4	0.03
29	Pennsylvania	16.1	0.03
30	Montana	0.5	0.02
31	District of Columbia	1.7	0.02
32	Wisconsin	4.7	0.02
33	Alabama	2.0	0.02
34	Rhode Island	1.1	0.02
35	New York	22.1	0.02
36	New Mexico	1.0	0.01
37	South Carolina	1.6	0.01
38	South Dakota	0.2	0.01
39	Massachusetts	4.8	0.01
40	Michigan	5.0	0.01
41	Arkansas	0.6	0.01
42	Wyoming	0.1	0.01
43	West Virginia	0.3	0.01
44	Alaska	0.2	0.01
45	Iowa	0.4	0.00
46	North Dakota	0.1	0.00
47	Maine	0.1	0.00
48	Minnesota	-0.1	NA
49	Hawaii	-0.8	NA
50	Louisiana	-1.3	NA
51	Vermont	-0.5	NA

NA means that the index is negative.
**Tech-ecommerce resilience index is calculated as the change in tech-ecommerce jobs divided by the absolute value of the change in private sector jobs.*
Data: PPI, BLS

CONCLUSION

We'll never see an era like the early part of the twentieth century, where one sector, manufacturing, was such a dominant driver of growth. Modern economies have become far too diversified for that.

However, in recent years, the tech-ecommerce ecosystem has become a prodigious creator of jobs, rivaling the post-war manufacturing sector in both absolute job creation and relative impact. As we saw in Table 4, from 1949 to 1979 manufacturing generated 205,000 net new jobs per year, accounting for 17% of private nonfarm job growth. Equivalently, from 2007 to 2019 the tech-ecommerce ecosystem generated 189,000 net new jobs per year, accounting for 18% of private nonfarm job growth.

Moreover, the tech-ecommerce leaders of today look very much like the industrial giants of yesterday, in both employment size and global scope. The parallels go deeper than that. As they grew, the industrial giants were subject to both antitrust scrutiny and labor pressure. Nevertheless, they kept hiring, and kept playing a central role in the economy. Today, Americans look back on that period, rightly or wrongly, as one of security and prosperity, and the industrial giants as avatars of that prosperity.

As we slowly emerge from the pandemic and the associated recession, we are not in a position yet to properly assess how today's era will be regarded by future eyes. But it is clear that the tech-ecommerce sector has taken manufacturing's place as America's job creation machine.

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5 There are other similarities between the five industrial giants and the five tech leaders. For one, global revenue of the five industrial giants was 5.1% of U.S. gross domestic product in 1979. Meanwhile, global revenue of the five tech leaders was also 5.1% of U.S. gross domestic product in 2020. And while we don't have full data on the domestic workforce of either the 1979 industrial giants or the 2020 tech leaders, the information that we do have suggests roughly similar domestic percentages. In 1979, roughly two-thirds of the industrial giant workforce was domestic, based on information from GM, IBM, Kodak, and DuPont. By comparison, in 2020 roughly 950,000 of Amazon's 1.3 million workers were located in the U.S, or 75% (https://www.aboutamazon.com/investing-in-the-u-s). Similarly, roughly 60% of Microsoft's 163,000 employees as of February 2021 were domestic. These two companies together also had a domestic workforce percentage of around two-thirds.

6 The methodology for setting starting dates were discussed in our 2017 report "An Analysis of Job and Wage Growth in the Tech/Telecom Sector." Our goal is to compare the employment growth among firms from different eras. The current tech firms are greenfield startups, in the sense that a new company was started from scratch and went public relatively soon afterward. For these companies the fiscal year of the IPO is the logical starting point. By comparison, most of the earlier big job creators—such as U.S. Steel, General Motors, and General Electric—were formed by merging several smaller, existing companies. For these companies, we picked the date of corporate formation that the company itself would pick as its beginning date. For example, we date the formation of GM from 1909 when William Durant, an entrepreneur and salesman in Flint, Michigan, rolled up 13 car companies and 10 parts-and-accessories manufacturers into one huge multi-brand manufacturer. General Electric was founded in 1892 as a merger of the Edison General Electric Company and the Thomson-Houston Electric Company. IBM started in 1911 as the Computing-Tabulating-Recording Company (C-T-R), which was a merger of the Tabulating Machine Company with the International Time Recording Company and the Computing Scale Company of America.

7 For this section, we rely on the BLS QCEW data, which is available at the state and county level.

8 These figures are based on a tabulation from the March 2019 Annual Social and Economic Supplement (ASEC) of the Current Population Survey. The QCEW contains no information on worker demographic characteristics. We use March 2019 rather than March 2020 to avoid overlapping with the early days of the pandemic.

9 Based on May 2019 Occupational Employment Survey data, which does not include annual bonuses.

10 We based our calculations in this section on BLS published data for 2020, "Labor Force Statistics from the Current Population Survey, Household Data, Annual Averages", Table 18, "Employed persons by detailed industry, sex, race, and Hispanic or Latino ethnicity." https://www.bls.gov/cps/cpsaat18.htm. We tabulated the underlying CPS microdata as well to confirm that rounding did not introduce significant differences in the percentages.

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