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AUTOMATION AND MANUFACTURING EMPLOYMENT IN WASHINGTON STATE

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Executive Summary

The relationship between automation and employment has become a leading area of research among economists and policymakers and source of a rich and growing literature. In this report, we explore this relationship as applied to Washington state's manufacturing sector. Analysis probes one fundamental and salient question often raised within policy circles: what effect has automation had on employment in the manufacturing sector in Washington state?

This study, commissioned by the Association of Washington Business (AWB), will help answer this question and support policy efforts to continue to bolster job creation and retention in the manufacturing sector.

Findings from this report show that automation in most cases in Washington does not lead to job losses in the manufacturing sector. Rather, automation is adopted for reasons of increasingly complex tasks, worker safety concerns, and improved quality control, and, in certain cases, the lack of available workers. Automation creates new types of human tasks complementary to the automated process. Automation that leads to increased productivity may reduce demand for new workers in the future, but it has not resulted in large scale separation of existing, incumbent workers. However, in some instances these workers are trained to do new tasks complementary to the automated process.

Trends in U.S. Manufacturing Labor Productivity and Employment

Although there is no readily available data on automation, economists have developed ways to address the data gaps. **Throughout this study, we measure the effect of automation by comparing gains in real labor productivity and employment in the manufacturing sector**.

In recent decades two trends point to increased automation:

- Until recently, sharp gains in manufacturing labor productivity.
- Increased capital investment per manufacturing worker.

Between 1980 and 2019 (earliest data available), manufacturing employment fell cumulatively more than 27%, while labor productivity more than doubled and industrial manufacturing production grew 77%. Between 1948 and 2018, labor productivity economywide (all sectors) grew at an average annual rate of 2.1% per year. However, between 2005 and 2018 this rate fell to just 1.4% per year.

There has been some reversal of these trends over the past decade. U.S. manufacturing labor productivity has stagnated since 2010. Between 2010 and 2019, manufacturing labor productivity fell 2.5%, while manufacturing employment increased 11.4%.

Growing investment in machinery

Capital expenditures per manufacturing worker grew in inflation-adjusted terms 31% overall between 2010 and 2019. Within the nondurable goods sector—including food and beverage products, chemicals, paper products, and textiles—capital expenditures increased from $19,400 per worker in 2010 to $27,600 in 2016 before slightly declining in 2017. Durable goods manufacturing capital expenditures, including aircraft, automobiles, and electronics, has remained fairly stable since 2011.

Automation and Employment in Washington State

Across the manufacturing sector, real gross business income per worker and real value-added (or GDP) per worker have far outpaced growth in manufacturing employment. These trends suggest that **fewer manufacturing workers are doing more**. Between 1998 and 2019, real value added per manufacturing worker increased 86%.

Factors behind automation investments

There are several possible reasons for adoption of automation. Some companies, such as fresh pack facilities, have been required by their customers (e.g., wholesalers and major supermarket chains) to implement new sorting and screening technologies to improve quality control. In these instances, while automaton has replaced human labor for specific tasks, the workers are often retained and given new tasks tied to the operation of these machines. Within the aerospace supply chain, new parts specifications may be too complex for a human to implement. Rote tasks such packaging products in cardboard boxes can be both time consuming and subject to human error. In all these instances, automation enhances human labor productivity.

In other cases, automation may be in response to labor force shortages. The share of Washington's manufacturing workforce is aging, as fewer new, younger workers enter the workforce. Some occupations may also be much more difficult to fill, due to an overall inadequate labor supply. These conditions may prompt employers to invest in automation to increase productivity of existing workers. Again, automation does not necessarily displace workers, but enhances the productivity capacity of incumbent workers.

CONTENTS

INTRODUCTION

The relationship between automation and employment has become a leading area of research among economists and policymakers and source of a rich and growing literature. In this report, we interrogate this relationship as applied to Washington state's manufacturing sector. Analysis probes one fundamental and salient question often raised within policy circles: What has been the effect of automation on employment in the manufacturing sector in Washington state?

This study, commissioned by the Association of Washington Business (AWB), will help answer this question and support policy efforts to continue to bolster job creation and preservation in the manufacturing sector. This analysis draws on the latest economic and public policy research, federal and state data sources on manufacturing employment and output, and news reports and articles.

Definitions and Terms

The following terms are used in this report:

- **Labor productivity**. The amount of goods and services produced (output) divided by the number of hours worked to produce those goods and services. Labor hours is often unavailable at the state level, and particularly so by sector, necessitating the use of alternative imperfect units of labor, such as a total full-time and part-time workers employed in manufacturing.
- **Multifactor productivity (MFP)**. Also referred to as total factor productivity (TFP). The amount of goods and services produced (output) divided by the amount of combined inputs used to produce those goods and services. Inputs can include labor, capital, energy, materials, and purchased services. Technological change is associated with changes in multifactor productivity not attributable to changes in productivity inputs.
- **Automation**. The substitution of machines and/or software for tasks traditionally done by humans, or "any instance where capital replaces labor as the source of value in the chain of production" (Gallup, 2020, p. 6).
- **Capital-skill complementarity**. The extent to which advancing technology (capital) complements or displaces highly skilled workers.
- **Skills-biased technological change**. Relationship between technology and skill that results in an increase in the relative demand for skilled workers related to unskilled workers as a result of their relationship to new technologies.
- **Job polarization**. A rising demand for workers in low- and high-skilled occupations relative to workers in middle-skilled occupations as a result of technology that has displaced routine manual and cognitive tasks.

- **Value-added**. Amount of value of an article generated at each stage of its production, less initial costs. Value-added is a representation of gross domestic product.
- **Gross business income (GBI)**. A measure of gross receipts, or gross revenues, inclusive of all carryover costs and value generated throughout the production process. GBI is an (imperfect) measure of output in Washington state and is not synonymous with value-added.

Organization of Report

The remainder of this report is organized as follows:

- **Relationship between automation and employment**. Review and summary of arguments and analysis and development of analytic framework.
- **Manufacturing employment and output per worker trends in Washington state**. A data-rich assessment of the impact of automation on employment using latest available data for Washington state.
- **Discussion of leading factors behind automation adoption**. Discussion based on interviews, articles, and news stories, on the role and impact of automation on employment.

RELATIONSHIP BETWEEN AUTOMATION AND EMPLOYMENT

Conceptual Framework for Assessing Automation and Employment

Automation, in broad terms, refers to technology solutions that replace humans in the operation of specific, often rote tasks. While automation may replace human labor, it can also enhance business and worker productivity, and spur the creation of new kinds of work. Kehal (2019) delineates three main types of automation:

- **Fixed automation**. The use of equipment to automate a repetitive (often non-complex) sequence of tasks, processing, assembly operations.
- **Programmable automation**. Allows for fresh programs to be designed and deployed to the system to implement new processes. Programmable automation allows for reprogramming for different tasks after a batch of one type is complete.
- **Flexible automation**. Involves the ability to switch between tasks and to be automatically adjusted.

Automation can have both positive and negative impacts on employment. Acemoglu and Restrepo (2019) conceptualize the impacts of automation obtaining through one of three possible mechanisms: 1) displacement effect; 2) productivity effect; and 3) reinstatement effect.

The *displacement effect* occurs when capital replaces human labor in the execution of a task, shifting the task content of production away from labor and thereby reducing the labor share. Displacement is most commonly found in low-skill jobs, though in recent years the types of tasks that can be automated have become increasingly complicated, enabled through developments in artificial intelligence (e.g., driverless cars, assembly line robotics).

However, displacement can be offset by the *productivity effect*, whereby "automation increases value added, and [raising] the demand for labor from non-automated tasks. If nothing else happened, labor demand of the industry would increase at the same rate as value added, and the labor share would remain constant" (Acemoglu & Restrepo, 2019, p. 8). The net effect of these two countervailing mechanisms—between reducing the share of labor and "increasing the size of the pie"—is not constant and will vary by technology, industry, and other factors.

Lastly, the authors identify a *reinstatement effect*, whereby new tasks created through capital investments "reinstate into a broader range of tasks and thus change the task content of production in favor of labor." The advent of computers displaced some workers, but also created new jobs in software engineering and programming, for example. The reinstatement effect directly increases both the labor share in the production of a good or service and labor demand (p. 3). It is also possible that workers displaced from one set of tasks due to automation may be retained to complete a new set of tasks complementary to the automated process. For example, in the food processing industry, workers displaced by the advent of sorting and screening machines can be retained, with new skills, to operate the new machinery or other related tasks.

In some scenarios, investments in automation may be driven by real or perceived labor shortages, either writ large across an entire labor market or for specific tasks that cannot be easily found. Numerous Chinese factories, for example, along China's East Coast and Southeast have made significant investments in automation and robotics in response to increasingly acute labor shortages and concomitant rising labor costs. Similar scenarios abound in other parts of the world where automation is not directly displacing labor, but in-filling tasks normally completed by labor that is now far more difficult to recruit and employ.

Automation and Employment: Evidence from the U.S. and Recent Studies

There is no existing data yet on the scale and impact of automation. However, instances where there is significant labor productivity growth combined with employment that is either stagnant or in decline may indicate increased automation.

Changes in employment due to automation may vary according to the nature of work and skills or type of work performed. The effects of productivity have been uneven over time, owing to economic shifts and the course and cadence of innovation. Economic historians have delineated three major industrial shifts or "revolutions" over the past two hundred fifty years: the original industrial revolution and role of water and steam in production, mass assembly and the Fordist era of industrialization, and the computer age. "Industry 4.0" represents the synchronization of computers, big data, and smart and autonomous systems fueled by data and machine learning. Applications include optimization of logistics and supply chains, robotics, drones, Internet of Things, and additive manufacturing (Marr, 2018). This new phase of industrialization has stoked concerns automation will accelerate and outpace upskilling of incumbent manufacturing workers, resulting in displacement.

The advent of automation is not new to the U.S. economy—many important advances in economic development came from the introduction of labor-saving or labor-substituting technologies. In earlier periods, the introduction of new technologies more often enhanced the productivity and wage earnings of workers, rather than displace labor. For example, Gordon (2017) finds that U.S. productivity gains and the most important innovations occurred between 1870 and 1970; more recent periods of productivity growth, punctuated by the advent of the computer and digital economy, have been much slower.

In their own research on the U.S. economy, Acemoglu and Restrepo (2019) found that in the period from 1947 to 1987, the displacement effect of automation was more than offset by the reinstatement effect and productivity growth (2.4% per year), resulting in rising real wages (2.5% per year) (p. 15). However, between 1987 and 2017, a different story has taken hold—weaker productivity growth (1.5% per year) and a slowdown in the reinstatement effect resulted in lower real wage growth (1.3% per year). In other words, decelerating labor demand nationally between 1987 and 2017 can be attributed to "a combination of anemic productivity growth and adverse shifts in the task contents of production owing to rapid automation that is not being counterbalanced by the creation of new tasks" (p. 16).

Acemoglu and Restrepo (2019) delineate two possible reasons for this shift. The first factor is a secular, structural change in the nature of innovation and the linkage between automation and creation of new tasks, resulting in further automation and the creation of new tasks becoming more difficult.

The second factor is policy: the authors cite a reduction in U.S. government R&D investments and elements in the U.S. tax code that favor automation over employment.

Labor Productivity Trends in the U.S.

Labor productivity is a key source of wealth creation and economic growth. In broad terms, an economy grows due either to working age population growth and/or gains in output per labor input, most often measured as labor hours.[1]

The contribution of capital intensity, also referred to as "capital deepening," is computed as capital's share of current dollar costs multiplied by the growth in capital services per labor hour. A growing contribution of capital intensity reflects a business's decision to invest in more equipment and other capital expenses relative to hiring more labor. Capital deepening is one mechanism by which automation can replace labor or enhance labor productivity. Labor composition refers to the types of workers employed in a firm. For example, a firm may replace low-skill workers with high-skill workers.

Multifactor productivity growth refers to the portion of output growth that is not accounted for by the growth of capital and labor inputs. This share is due to contributions of other inputs, "such as technological advances in production, the introduction of a more streamlined industrial organization, relative shifts of inputs from low to high productivity industries, increased efforts of the workforce, and improvements in managerial efficiency" (Sprague, 2021).

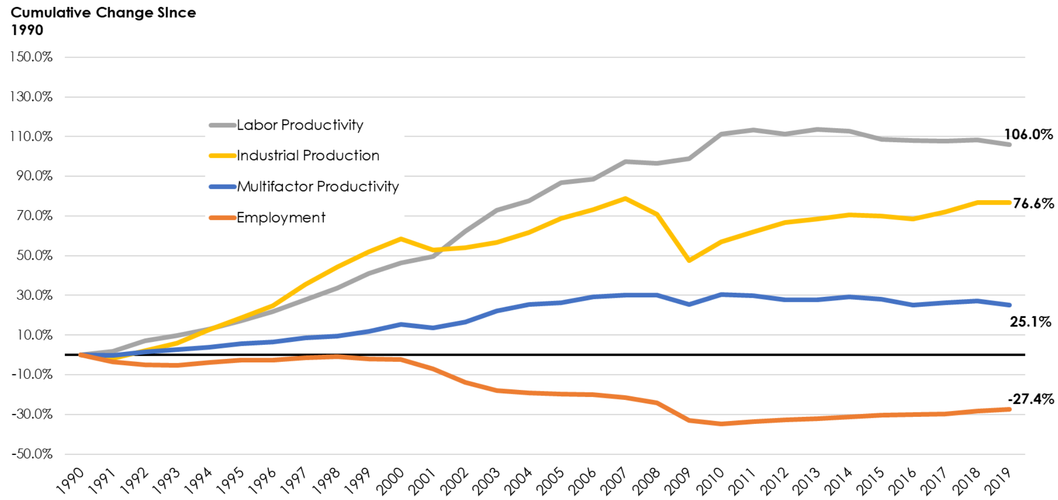
Between 1980 and 2019 (earliest data available), manufacturing employment fell cumulatively more than 27%, whilst labor productivity more than doubled and industrial manufacturing production grew 77% (**Exhibit 1**). U.S. multifactor productivity (inflation adjusted) across all sectors increased at an annual rate of about 0.6% per year, or approximately 29% overall over the 39-year period.

However, there has been some reversal of these trends over the past decade. U.S. manufacturing labor productivity has stagnated since 2010. Between 2010 and 2019, manufacturing labor productivity fell 2.5%, while manufacturing employment increased 11.4%.

[1] Labor productivity growth, or the measure of output per labor input (hour), can be described as follows:

Labor productivity growth = multifactor productivity growth + contribution of capital intensity + contribution of labor composition

Exhibit 1. U.S. National Manufacturing Employment, Productivity, and Production, Compared to 1990



Sources: U.S. Bureau of Labor Statistics (2020; 2021); U.S. Bureau of Economic Analysis (2020).

The decline in manufacturing labor productivity follows, albeit a few years behind, an economywide trend of declining labor productivity. Between 1948 and 2018, labor productivity economywide grew at an average annual rate of 2.1% per year. However, between 2005 and 2018 this rate fell to just 1.4% per year. The contribution of capital intensity fell from a historic average of 0.9% to 0.7%, while multifactor productivity growth fell from a historic average of 1.1% to 0.4%. Moreover, even the surge in labor productivity between 1997 and 2005, at 3.3% growth per year, has been viewed by Gordon (2017) and others as an anomaly in the long-term historic trend.

The impact of technology and technology diffusion on labor demand may vary by industry. Some research has suggested these differences may arise between industries that produce technology, e.g., software publishing, electronics, and those that are simply users of technology.

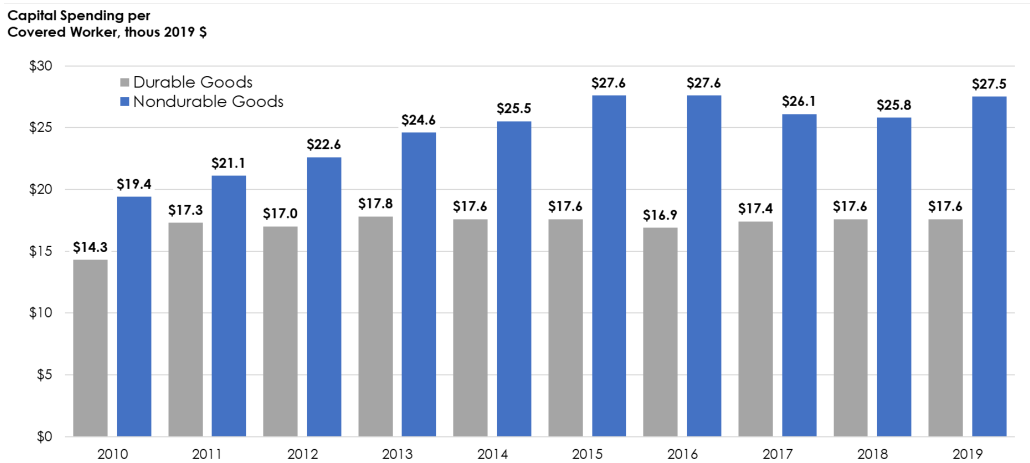
For example, Autor and Dorm (2013) found that occupational growth between 1980 and 2005 was much greater for low and high-paying jobs, relative to "middle-skill" jobs, including manufacturing production workers and clerical workers. Some of this "hollowing" out or *polarization* may be attributable to automation, but there is also a large impact of expanding overseas labor markets, particularly low-cost labor in developing countries, that likely also contributed to this outcome.

In a study of industry-level data across developing countries, Autor and Salomons (2018) found that multifactor factor productivity increases—a measure of technology adoption—coincided with decreases in employment and a reduction in the labor share of income. According to their analysis, "technological progress is broadly employment-augmenting in the aggregate

[but] this is not so for labor’s share of value-added, where direct labor-displacing effects dominate” (p. 35).

Growth in capital expenditures can reflect an increasing role of robotics and automation in the manufacturing sector. Capital expenditures per manufacturing worker grew in inflation-adjusted terms 31% overall between 2010 and 2019. Within the nondurable goods sector—including food and beverage products, chemicals, paper products, and textiles—capital expenditures increased from $19,400 per worker in 2010 to $27,600 in 2016 before slightly declining in 2017. Durable goods manufacturing, including aircraft, automobiles, and electronics, has remained fairly stable since 2011 (**Exhibit 2**).

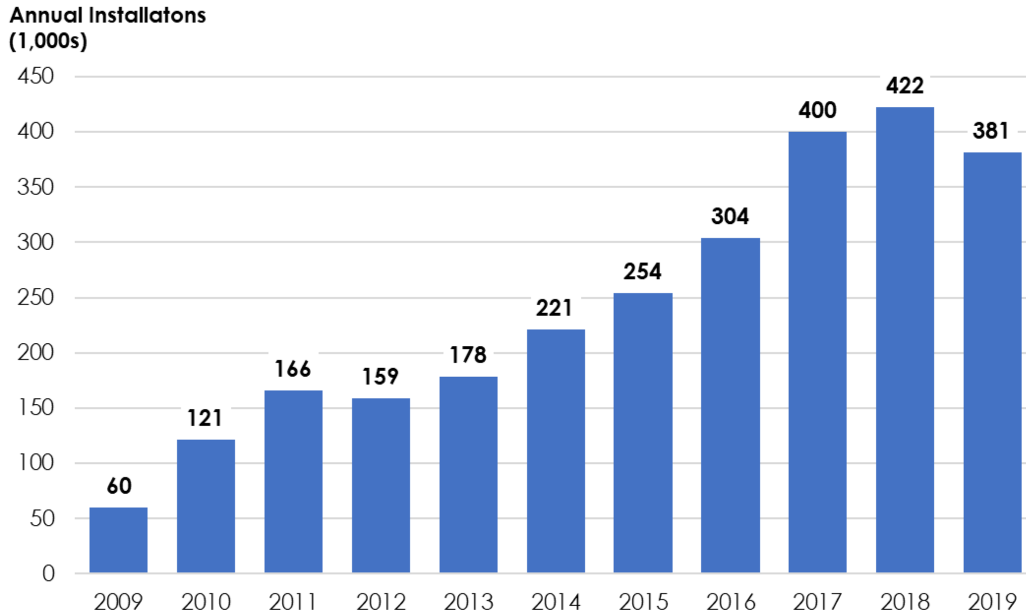
Exhibit 2. Manufacturing Capital Expenditures per Covered Worker, U.S., 2010-2019



Source: U.S. Census Bureau (2021).

According to data compiled by the International Federation of Robotics (2020), investment in industrial robots globally, measured in robotic units, increased at an annual compound rate of 24% per year between 2009 to 2018, reaching 422,000 new units in 2018, before dropping slightly in 2019 (**Exhibit 3**). The majority of these investments have been in Asia, primarily China, as the primary nexus for various electronics, automotive, and machinery manufacturing. Within the Americas, industrial robot units increased 14% each year (compound annual growth rate) between 2010 and 2019. Globally, in 2019 the largest concentration of new installed units was in the automotive sector (28%), followed by electrical products and electronics (11%).

Exhibit 3. Global New Installations of Industrial Robots, 2009-2019



Source: International Federation of Robotics (2020).

Measuring the Impact of Automation in Washington State

Key Indicators

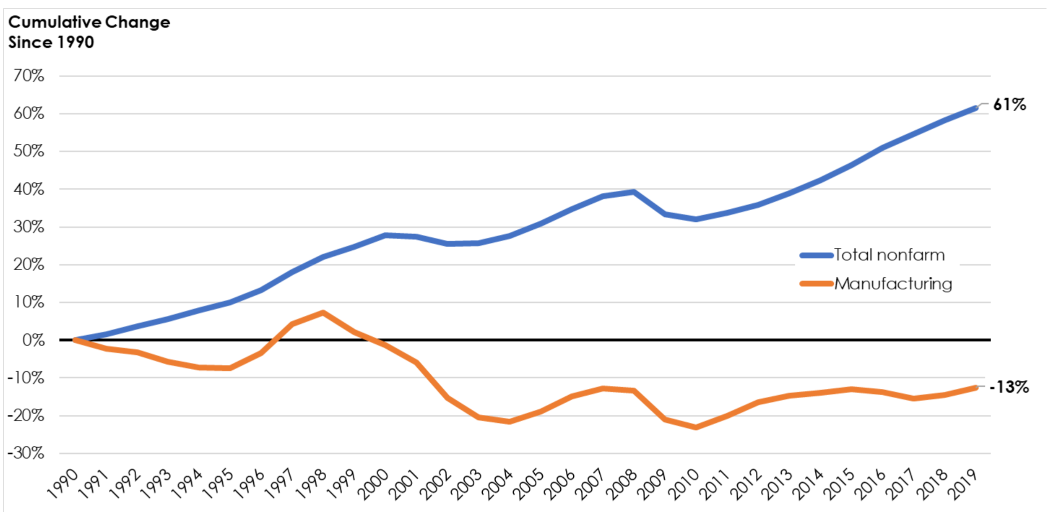
Data sources needed to evaluate the impacts of automation in manufacturing are quite limited. Federal and state agencies do not report sectoral productivity measures at the state level, nor the actual number of labor hours per sector. However, there are alternative measures that can be used to approximate these impacts. With these limitations in mind, in order to assess the impacts of automation on manufacturing employment in Washington state, we examine the following:

- **Manufacturing employment over time**. Gains and losses in the manufacturing sector.
- **Overall labor productivity changes over time in manufacturing**. Increased labor productivity can have an offsetting impact on current and future employment.
- **Creation of new kinds of jobs**. Within the manufacturing sector, the emergence of new kinds of work or rapid expansion of new occupations and skills, evidencing the *reinstatement effect* discussed above.

Manufacturing Employment Change Over Time in Washington State

Between 1990 and 2019, private sector manufacturing statewide employment declined approximately 13%, losing nearly 42,600 jobs over this period (Washington State Employment Security Department, 2021). As a share of nonfarm employment, since 1990 manufacturing jobs have fallen from 15.7% to 8.4%, or down by close to half. Put differently, while manufacturing jobs have declined in absolute terms, nonfarm employment grew by 61% over the same period (**Exhibit 4**).

Exhibit 4. Manufacturing and Total Nonfarm Employment, Washington State, Cumulative Change Since 1990, 1990-2019

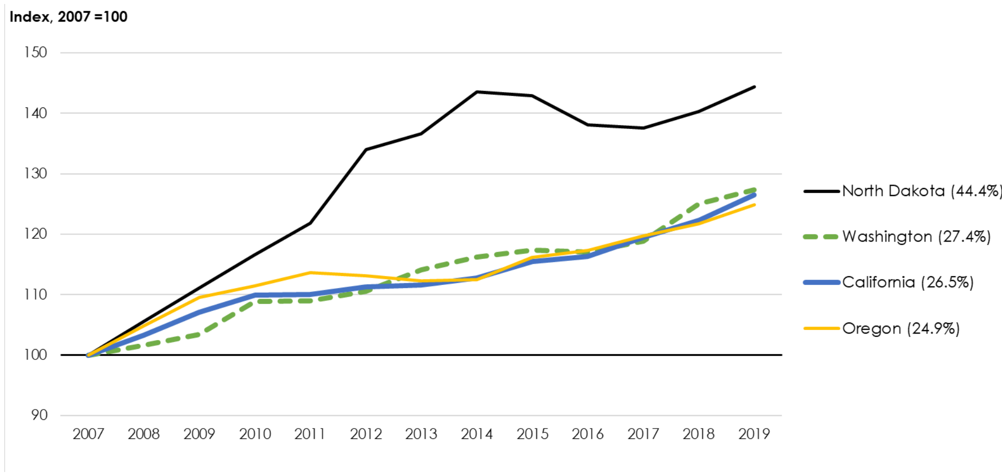


Data source: Washington State Employment Security Department (2021).

Labor Productivity in Washington State

Statewide, across all sectors of the Washington economy, private nonfarm labor productivity grew 2.0% per year between 2007 and 2019, and 2.1% per year between 2009 and 2019 (U.S. Bureau of Labor Statistics, 2020). Washington's growth in labor productivity growth over this period ranked second only to North Dakota, the latter buoyed by the until recent rapid expansion in oil and gas extraction. Cumulatively, Washington's real labor productivity over the 2007 to 2019 period grew 27.4%, followed by California and Oregon (**Exhibit 5**).

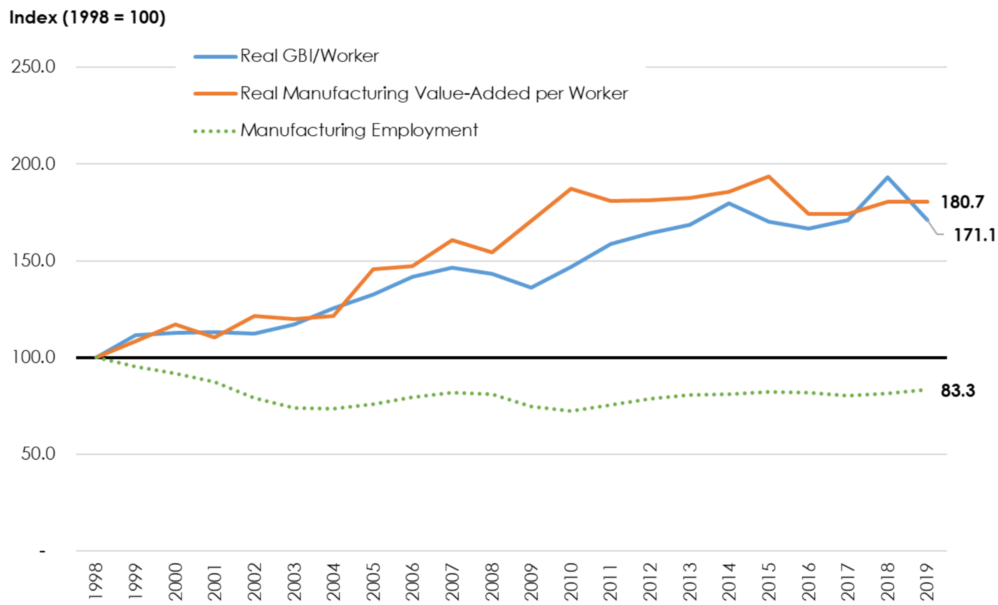
Exhibit 5. State-Level Private Nonfarm Real Labor Productivity Growth, 2007-2019 (Indexed, 2017 = 100), Top Four States for Growth, <u>All Sectors</u>



Data source: U.S. Bureau of Labor Statistics (2020).

There is currently no available data on labor productivity in the manufacturing sector at the state level. However, real gross domestic product per worker offers a reasonable proxy for manufacturing productivity. Between 1998 (earliest available year) and 2019, real manufacturing gross domestic product per worker (or real value-added per worker) increased 81%, or at a compound annual growth rate of 2.9%. An alternative measure is real gross revenues or sales (i.e., gross receipts) per worker over time. Between 1998 and 2019, gross business income (GBI) in the manufacturing sector in Washington state, in inflation-adjusted real terms, grew 43%, or about 1.7% per year (in 2018, real manufacturing GBI reached a peak of $212.9 billion, or 2.3% per growth since 1998). On a per worker basis, real GBI per worker increased 71% between 1998 and 2019. Employment in manufacturing is nearly 17% below its level in 1998 (**Exhibit 6**).

Exhibit 6. Washington State Manufacturing Employment, Manufacturing Real Gross Business Income per Worker, and Manufacturing Real GDP per Worker, Indexed to 1998 (100)



Data sources: U.S. Bureau of Economic Analysis (2020; 2021); U.S. Bureau of Labor Statistics (2020); Washington State Department of Revenue (2021).

Diversification of Employment and Work within Manufacturing

Changes in the occupational mix within manufacturing over time may offer another indication as to the growing reliance on automation. A growing reliance or share of manufacturing employment in the fields of engineering or other STEM-related positions may suggest greater investment in advanced machinery and equipment, and growing demand for skills needed for the use of this equipment.

However, there is no clear evidence this trend is happening in Washington state. Between 2012 (earliest available year) and 2019, the share of "architecture and engineering" occupations in total manufacturing actually declined, from 11.3% to 9.5%. Some of this skills training may be occurring in the form of on-the-job training. It may also be included as part of an upgrading of existing curricula for various vocational programs. In other words, a firm may employ the same number of welders, metal fabricators, machinists, or packers, but these workers have received new skills integral to their work, rather than being replaced by workers with tech-specific degrees.

Measuring Changes in Productivity and Employment by Subsector

Within the manufacturing sector, there is some notable variation in employment change. Between 1997 and 2019, some subsectors, such as "food and beverage and tobacco products" (+6,900 jobs) and "fabricated metal products" (+2,700) exhibited net job growth. However, others, such as "computer and electronic products" (-13,600 jobs) and "other transportation equipment" (-12,900) experienced significant contractions over the same period (**Exhibit 7**).

Among the 19 subsectors reported by the U.S. Bureau of Economic Analysis (2020), 11 experienced net declines in employment between 1997 and 2019. Among these, all experienced real GDP/worker increases over the same period. Computer and electronic products manufacturing, similar to national trends, is a data anomaly—net real GDP per covered worker increased nearly 2500% between 1997 and 2019, while employment fell by more than 40%. Using real GBI per worker instead of real GDP per worker, broken out by the 20 largest manufacturing subsectors by 4-digit North American Industry Classification System (NAICS) code, yields similar results (**Appendix A**). **The data in many of these manufacturing subsectors suggests that employers are able to generate more output per labor unit.**

Exhibit 7. Changes in Employment and Real GDP per Worker in Washington's Manufacturing Sector, 1994-2019

Subsector	**Employment** *1997*	**Employment** *2019*	**Net change** *1997-2019*	**Percent change** *1997-2019*	**Change in real GDP per Worker** *1997-2019*
Other transportation equipment	120,800	107,900	**-12,900**	**-11%**	45.3%
Food and beverage and tobacco products	42,600	49,500	6,900	16%	4.6%
Computer and electronic products	33,300	19,700	**-13,600**	**-41%**	2485.4%
Wood products	22,600	12,700	**-9,900**	**-44%**	73.3%
Fabricated metal products	18,200	20,900	2,700	15%	14.1%
Paper	15,600	7,800	**-7,800**	**-50%**	5.6%
Machinery	14,000	15,600	1,600	11%	38.6%
Printing and related support activities	12,000	5,400	**-6,600**	**-55%**	112.3%
Primary metals	11,800	5,200	**-6,600**	**-56%**	187.3%
Miscellaneous	11,300	11,700	400	4%	70.4%
Plastics and rubber products	10,000	8,500	**-1,500**	**-15%**	41.5%
Nonmetallic mineral products	8,500	9,500	1,000	12%	46.5%
Furniture and related products	7,700	6,100	**-1,600**	**-21%**	17.5%
Chemicals	6,100	7,400	1,300	21%	33.9%
Apparel, leather, and allied products	5,800	1,900	**-3,900**	**-67%**	109.8%
Motor vehicles, bodies and trailers, and parts	4,200	3,300	**-900**	**-21%**	226.3%
Textile mills and textiles	4,000	2,500	**-1,500**	**-38%**	41.1%
Electrical equipment, appliance, and components	3,400	5,000	1,600	47%	44.9%
Petroleum and coal products	2,200	2,800	600	27%	108.1%

Data sources: U.S. Bureau of Economic Analysis (2020; 2021); U.S. Bureau of Labor Statistics (2020).

DISCUSSION AND CONCLUSIONS: FACTORS THAT CAN DRIVE AUTOMATION INVESTMENTS

Several key factors may be driving manufacturing automation investments in Washington. These include:

- **Labor shortages**. Manufacturers are finding it increasingly difficult to find workers for specific skills, e.g., welding. Automation investments help ameliorate these labor shortages that directly impact a business's ability to meet production targets and remain competitive.
- **Supply chain requirements**. Manufacturers may be required by downstream customers to implement automation and automated processes, regardless of the availability or cost of labor. This is particularly the case in the food processing sector, where manufacturers are often requested by their downstream customers (e.g., wholesalers, retailers) to implement new technologies that are designed, for the purpose of improving food safety and sanitation, to remove humans from certain processes.
- **Task complexity**. In other instances, the type of manufacturing process may be too complex for a human to complete in the time needed and at a specific quality level. For example, powder coating. In other instances, human speed in completing a task may be insufficient relative to production line needs.
- **Worker safety**. Some types of manufacturing tasks have become too hazardous for humans to implement, necessitating use of robots and other machines in lieu of human labor.

We spoke with several Washington manufacturers and industry experts about automation and its relationship with labor. Based on these interviews and data presented above, we found no evidence that manufacturers sought to replace incumbent workers with automated processes and machines. However, there are some notable factors shaping the demand for automation, discussed below.

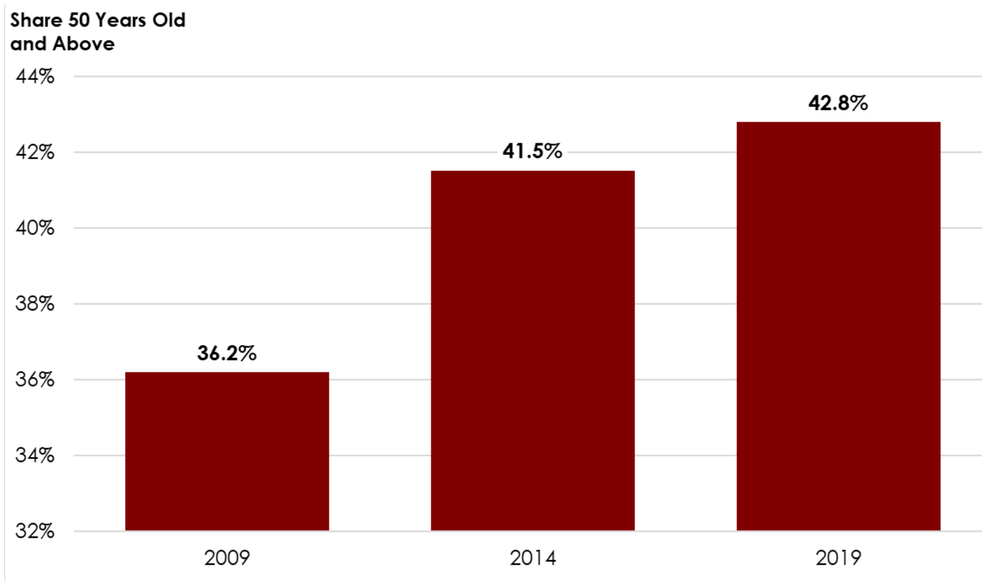
Labor Force Dynamics

The data above presents circumstantial, but not definitive, evidence of automation and its impacts on manufacturing employment in Washington state. Washington's incumbent workforce and manufacturers face two additional key issues. Some manufacturers interviewed for this work indicated it can be very difficult to find and employ certain high skill workers, such as welders. Perceived labor shortages and an aging workforce edging towards retirements may serve as push factors towards adoption of labor-substituting technologies to address potential hiring challenges (not displacement of incumbent workers).

Washington's manufacturing labor force is aging; between 2009 and 2019, the share of manufacturing workers 50 years of age and older increased from 36% to 43% (**Exhibit 8**). An estimated 49% of machinists and 43% of both "First-Line Supervisors of Production and Operating Workers" and

"Inspectors, Testers, Sorters, Samplers, and Weighers" are 50 years of age or older (U.S. Census Bureau, 2020).

Exhibit 8. Share of Washington's Manufacturing Workforce Ages 50 and Above: 2009, 2014, and 2019



Source: U.S. Census Bureau, ACS 5-Year Estimates – Public Use Microdata Sample (2020).

Many of the most common manufacturing positions do not require a high level of educational attainment. In 2020, an estimated 69% of manufacturing workers were in positions that did not require a college degree of higher. Of these positions, 54% of workers were employed in occupations that required only a high school degree or equivalent (**Exhibit 9**). Automation technologies may first affect positions that require less technical skill, though skill doesn't necessarily correlate with educational attainment level; many technical skills can be acquired on the job.

Exhibit 9. Share of Washington's Manufacturing Workforce by Common Educational Attainment Requirement for Occupation, 2020

Educational Attainment Level Required	Share of Manufacturing Employment
No formal educational credential	11%
High school diploma or equivalent	54%
Some college, no degree	1%
Associate's degree	3%
Bachelor's degree	24%
Postsecondary nondegree award	7%
Master's degree	0%
Doctoral or professional degree	0%
Less than a college degree	*69.3%*
College degree of higher	*30.7%*

Sources: Washington State Employment Security Department (2020a; 2020b).

Supply Chain Requirements

A pull factor towards automation may be largely external—pressure to adopt new technologies from clients and higher tier businesses within a supply chain. According to one interviewee, the growing push to continually improve health and safety in domestic food systems has resulted in adoption of assembly and packaging line robotics and systems that replace humans. However, these technologies typically do not have a net negative effect on employment since they create new kinds of work elsewhere on the factory floor or fruit and vegetable fresh-pack facility. Or, for example, when an original equipment manufacturer (OEM) in a supply chain introduces new specifications that can only be implemented using robotics.

Task Complexity

Some tasks have become so complex they exceed the capabilities of human labor, or at least the volumes and speeds necessary for a given business process. For example, in packaging for manufactured components, or applications that require a degree of precision difficult if not impossible to achieve with human labor alone.

Worker Safety

Worker health and safety is another important factor. As manufacturing tasks become more complex and production volumes grow, there is often an increased risk of worker injury. Robotic arms, mobile robotic platforms, and integrated automation systems can significantly reduce the risk of injury and enhance the productivity of the incumbent worker. In many cases, the worker learns new skills related to the operation and monitoring of the new machine, such as programming tasks and maintenance.

Conclusions

Automation is not a new phenomenon. Since the Industrial Revolution, producers have sought to boost productivity, increase quality, and reduce costs. Automation, along with improved product and workplace design and elevated workforce skills, is part of the natural evolution of the manufacturing process. As such, it is difficult empirically to isolate the effects of automation from other factors contributing to productivity gains. Nonetheless, using available data, it is possible to identify some recent trends.

Findings from this report show that automation in most cases in Washington does not lead to job losses in the manufacturing sector. Rather, automation is adopted for reasons of increasingly complex tasks, worker safety concerns, and improved quality control, and, in certain cases, the lack of available workers. Automation creates new types of human tasks complementary to the automated process. Automation that leads to increased productivity may reduce demand for new workers in the future, but it has not resulted in large scale separation of existing, incumbent workers. However, in some instances these workers are trained to do new tasks complementary to the automated process.

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APPENDIX

Appendix A. Changes in Employment and Real Gross Business Income per Worker in Washington's Manufacturing Sector, 1994-2019 (20 Largest Subsectors in 2019)

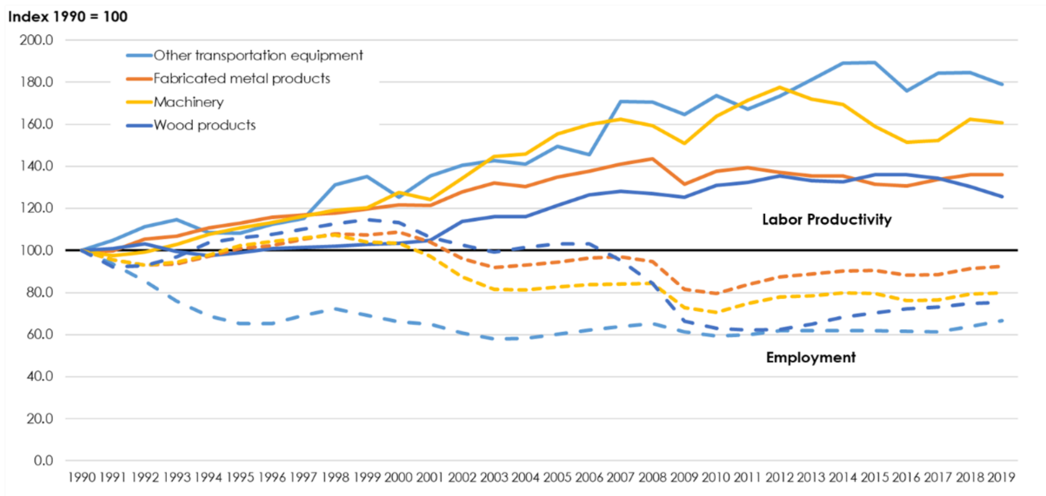
Manufacturing Subsector	Jobs 1994	Jobs, 2019	Net Job Change *1994-2019*	Percent Change *1994-2019*	Contribution to State Jobs Change	Change in Real GBI/worker
Aerospace product and parts manufacturing	91,290	88,480	-2,810	-3.1%	-0.6%	119.9%
Fruit and vegetable preserving and specialty	12,620	11,800	-820	-6.5%	-0.2%	40.4%
Printing and related support activities	23,550	10,760	-12,790	-54.3%	-2.7%	-116.5%
Beverage manufacturing	3,240	10,380	7,140	220.4%	0.5%	21.3%
Electronic instrument manufacturing	10,410	10,110	-300	-2.9%	-0.1%	234.4%
Ship and boat building	9,680	9,310	-370	-3.8%	-0.1%	183.1%
Architectural and structural metals mfg.	6,370	8,870	2,500	39.2%	0.2%	200.6%
Plastics product manufacturing	8,060	8,200	140	1.7%	0.0%	135.7%
Other miscellaneous manufacturing	6,800	7,210	410	6.0%	0.0%	255.3%
Semiconductor and electronic component mfg.	6,190	7,000	810	13.1%	0.1%	160.4%
Bakeries and tortilla manufacturing	6,400	6,230	-170	-2.7%	0.0%	67.2%
Sawmills and wood preservation	8,170	5,780	-2,390	-29.3%	-0.5%	12.4%
Animal slaughtering and processing	3,460	5,530	2,070	59.8%	0.1%	-19.1%
Seafood product preparation and packaging	8,670	5,490	-3,180	-36.7%	-0.7%	100.0%
Machine shops and threaded product mfg.	3,190	5,320	2,130	66.8%	0.1%	274.0%
Other food manufacturing	3,470	5,220	1,750	50.4%	0.1%	274.9%
Other general purpose machinery manufacturing	2,300	5,140	2,840	123.5%	0.2%	259.7%
Cement and concrete product manufacturing	4,190	4,640	450	10.7%	0.0%	31.5%
Other wood product manufacturing	10,010	4,570	-5,440	-54.3%	-1.1%	-29.6%
Medical equipment and supplies manufacturing	2,830	4,490	1,660	58.7%	0.1%	19.0%

Indicates negative growth.

Data sources: U.S. Bureau of Economic Analysis (2020; 2021); U.S. Bureau of Labor Statistics (2020); Washington State Department of Revenue (2021).

Appendix B. U.S. National Manufacturing Employment by Subsector and Labor Productivity Indexed to 1990 (100)

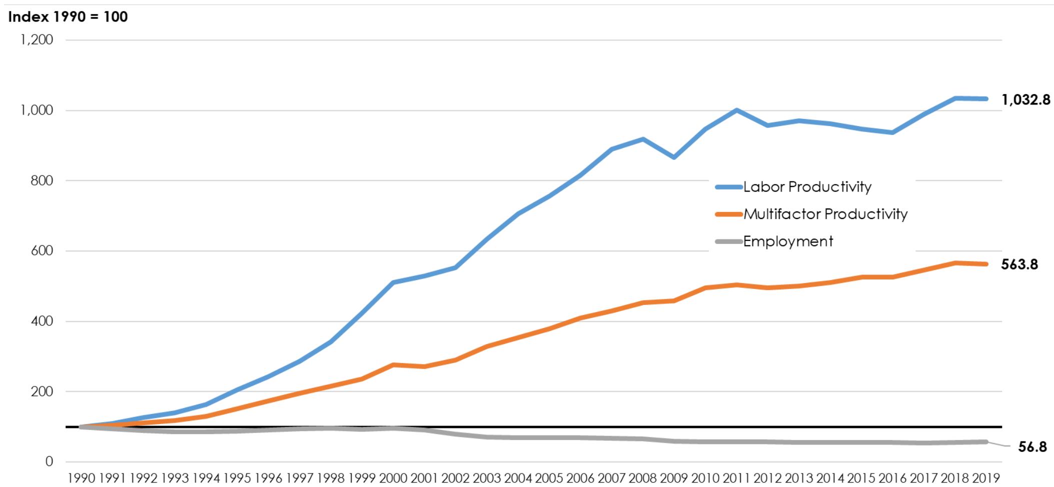
There is wide variation in labor productivity and employment changes since 1990 within the manufacturing sector, with other transportation equipment (a subsector that includes aerospace), fabricated metal products, machinery, and wood products all showing lower labor productivity gains over this period In the case of "other transportation equipment," multifactor productivity in 2019 essentially did not change compared with the 1990s.



Source: U.S. Bureau of Labor Statistics (2020).

Appendix C. U.S. Labor Productivity and Employment, Computer and Electronic Products Manufacturing, Growth Index (1990 = 100)

However, some subsectors of manufacturing have seen much larger and rapid growth in productivity. The largest gains, for example, have been in computer and electronic product manufacturing, which employed nearly 1.1 million workers in 2019. Employment has fallen more than 50% since 1990, while labor productivity increased 900% and multifactor productivity more 450%.



Source: U.S. Bureau of Labor Statistics (2020).

Appendix D. Interviews

The following interviews and organizations were interviewed to solicit their inputs, perspectives, and insights into automation in manufacturing for this report.

Individual	Affiliation
Allison Budvarson	Out-of-the-Box
Grant Forsyth	Avista Corporation
Spencer Foxworth	Graysam Robotic Systems
Chat Moutray	National Association of Manufacturers (NAM)
Desmond O'Rourke	Belrose, Inc.
David Rankin	Rankin Equipment
Michael Senske	Pearson Packaging