LISA ABRAHAM, CHRISTINE MULHERN, LUCAS GREER

Strengthening the Manufacturing Workforce in Ohio
About This Report

This research report summarizes the employment patterns in Ohio’s manufacturing sector and the pipeline between Ohio’s postsecondary education system and manufacturing employment. Manufacturing employers often cite challenges to finding and hiring a sufficient number of highly skilled and diverse workers. This research examines the current status of pathways into manufacturing and retention of manufacturing workers and how the workforce can be expanded and made more diverse.

RAND Education and Labor

This study was undertaken by RAND Education and Labor, a division of the RAND Corporation that conducts research on early childhood through postsecondary education programs, workforce development, and programs and policies affecting workers, entrepreneurship, and financial literacy and decisionmaking. This study was sponsored by the Lumina Foundation, which is committed to helping redesign learning after high school and make learning more accessible.

More information about RAND can be found at www.rand.org. Questions about this report should be directed to Lisa Abraham (labraham@rand.org) or Christine Mulhern (cmulhern@rand.org), and questions about RAND Education and Labor should be directed to educationandlabor@rand.org.

Acknowledgments

We are grateful to the Lumina Foundation for funding this work and to Wendy Sedlak, Kermit Kaleba, and Frank Essien for participating in many helpful conversations. We thank partners in Ohio, including the Ohio Department of Education, Ohio Manufacturers’ Association, and Ohio Longitudinal Data Archive (OLDA), for helpful conversations and for sharing the data needed to conduct this research. The OLDA is a project of the Ohio Education Research Center (oerc.osu.edu) and provides researchers with centralized access to administrative data. The OLDA is managed by The Ohio State University’s CHRR (chrr.osu.edu) in collaboration with Ohio’s state workforce and education agencies (olda.ohio.gov), with those agencies providing oversight and funding. For information on OLDA sponsors, see http://chrr.osu.edu/projects/ohio-longitudinal-data-archive. We are also grateful for valuable comments from Lindsay Daugherty, Peter Bahr, Stephanie Rennane, Sara Tracey, and Melanie Zaber.
Summary

Manufacturing employers often cite challenges to finding and hiring a sufficient number of highly skilled and diverse workers, so it is important to understand how pathways into manufacturing and the retention of manufacturing workers may be improved. In this report, we address this research gap by leveraging administrative educational and employment data from the Ohio Longitudinal Data Archive, allowing us to examine the pipeline between Ohio’s postsecondary education system and manufacturing employment and the manufacturing workforce more broadly. We focus on understanding potential ways to improve the available supply of workers and the diversity of the manufacturing workforce. Although Ohio represents a subset of the U.S. manufacturing industry, it has a significant share of manufacturing employment and production and, thus, can be instructive for understanding the challenges and opportunities that workers, employers, and educational institutions in the industry face.

In Chapter 1, we discuss the state of the manufacturing industry within Ohio and in the United States, as well as challenges to recruiting a diverse manufacturing workforce. In Chapter 2, we use data from the American Community Survey to examine how manufacturing workers in Ohio compare with those in the rest of the United States in terms of their demographic characteristics, educational backgrounds, and earnings. In Chapters 3, 4, and 5, we use administrative data from Ohio to examine the characteristics of students in Ohio who pursue manufacturing-related education programs and the characteristics of manufacturing workers in Ohio. These data allow us to examine attrition from education to employment, as well as earnings, retention, and upskilling patterns in Ohio's manufacturing industry. Chapter 6 summarizes potential avenues for expanding and diversifying Ohio's manufacturing workforce.

This report has some limitations. First, our analysis focuses on Ohio and, thus, does not perfectly represent the rest of the United States. We mitigate this limitation by contextualizing the differences between Ohio and the rest of the United States in Chapter 2. Second, because of data constraints, we were not able to analyze the coronavirus disease 2019 (COVID-19) and post–COVID-19 period using the administrative Ohio education data. Third, we were only able to examine employment and wage information for workers in unemployment insurance–eligible Ohio jobs. Thus, people who moved out of Ohio are not reflected in our data, nor are federal workers or self-employed individuals. Fourth, the education data have some limitations: (1) Records for people who went to private schools or received their education out of state are excluded; (2) we only have educational records from 2006 to 2019 and, thus, were unable to assess the educational background of the majority of Ohio’s manufacturing workers, especially those workers who are older and would have completed their education earlier; (3) we are not able to observe students’ career intentions, so our definition of “manufacturing” students is based on a somewhat broad definition of students who enroll in or complete a manufacturing-related credential; (4) data on the Ohio Technical Centers (OTCs) are available with consistency only from 2013 onward, and we are able to observe course completions only at OTCs; and (5) because of errors in the data on certificate enrollments from the Ohio Department of Higher Education, we do not report statistics based on certificate enrollment. Finally, the Ohio data that we leveraged do not include occupational information, so we were not able to perform detailed analyses examining differences by occupation or analyses of workers’ career trajectories in terms of their occupations.
Contents

About This Report .......................................................................................................... iii
Summary ...................................................................................................................... v
Figures and Tables ........................................................................................................ ix

CHAPTER 1
Challenges for the Manufacturing Industry ........................................................................ 1
Status of the Manufacturing Industry .............................................................................. 1
Challenges to Recruiting a Diverse Manufacturing Workforce ........................................ 3
Manufacturing in Ohio .................................................................................................. 3
Education as a Pathway for Expanding and Strengthening the Manufacturing Workforce ......................... 4
Framework for Understanding Knowledge Gaps ............................................................... 5
Summary .................................................................................................................... 7

CHAPTER 2
Education, Earnings, and Career Trajectories of Manufacturing Workers in Ohio and the Rest of the United States .............................................................................................. 9
Characteristics of Manufacturing Workers in Ohio Versus the Rest of the United States .................................................. 9
Earnings of Manufacturing Workers in Ohio Versus the Rest of the United States ................. 11
Summary ................................................................................................................... 12

CHAPTER 3
Manufacturing-Related Education in Ohio ........................................................................ 13
Ohio Higher Education and Employment Data ..................................................................... 13
Overall Trends in Manufacturing-Related Enrollments and Completions .................................................. 14
Industries of Employment of Students in Manufacturing-Related Programs .................... 16
Manufacturing Students’ Wages ...................................................................................... 18
Summary ................................................................................................................... 20

CHAPTER 4
Manufacturing Workers in Ohio ......................................................................................... 21
Ohio Employment Data .................................................................................................. 21
Manufacturing Workers’ Wages ...................................................................................... 22
Manufacturing Workers’ Retention ................................................................................ 22
Summary ................................................................................................................... 25

CHAPTER 5
Pathways into Manufacturing for Recent Entrants ................................................................ 27
Recent Entrants ............................................................................................................ 27
Potential Avenues into the Manufacturing Industry .......................................................... 28
Retention and Upskilling ................................................................................................ 29
Summary ................................................................................................................... 31
CHAPTER 6
Potential for Expanding and Diversifying Ohio’s Manufacturing Workforce ........................................ 33

APPENDIXES
A. Additional Details on Data Sources and Methods ...................................................................... 37
B. Additional Tables and Figures ...................................................................................................... 41

Abbreviations ........................................................................................................................................ 51
References ............................................................................................................................................... 53
Figures and Tables

Figures

1.1. U.S. Manufacturing Employment ................................................................. 1
1.2. Manufacturing Employment in Ohio .......................................................... 4
1.3. Understanding Ohio’s Manufacturing Workforce ....................................... 7
3.1. Enrollments and Completions in Ohio Manufacturing-Related Programs .......... 15
3.2. Median Wages Among Manufacturing Students One Year After Finishing Credential, by Credential Type and Industry of Employment ........................................ 19
4.1. Full-Time Ohio Manufacturing Workforce ................................................. 22
4.2. Number of Full-Time Manufacturing Workers and Median Wages, by Gender ........ 23
4.3. Number of Full-Time Manufacturing Workers and Median Wages, by Age .......... 23
4.4. Attrition from Ohio Manufacturing Industry .............................................. 24
5.1. Share of Full-Time Manufacturing Workers in 2013 Who Subsequently Pursued Postsecondary Education .......................................................... 30
B.1. Retention of Students in the Manufacturing Pipeline, by Density of Manufacturing Establishments ............................................................ 47
B.2. Median Full-Time Earnings Changes for Switchers .................................... 47
B.3. Attrition from Ohio Manufacturing Industry: Recent Cohorts ....................... 48
B.4. Average Earnings of Manufacturing Workers Who Pursued Postsecondary Education (2021 U.S. dollars) ........................................................... 49

Tables

2.1. Demographics of Ohio Versus the Rest of the United States: Manufacturing as of 2019 ................................................. 10
3.1. Manufacturing-Related Enrollments and Completions as of 2019, by Race/Ethnicity and Gender .......................................................... 15
3.2. Attrition from Manufacturing-Related Education to Manufacturing Employment, by Credential Type .......................................................... 16
3.3. Attrition from Manufacturing-Related Education to Manufacturing Employment, by Demographic Group .......................................................... 17
5.1. Supply of Manufacturing Workers .............................................................. 28
A.1. Characteristics and Match Rates of Samples Used for Analyses .................... 39
B.1. Top U.S. States with Full-Time, Working-Age Manufacturing Workers ................. 41
B.2. Top Three Occupations, by Race/Ethnicity and Gender .................................. 41
B.3. Demographic Composition of Ohio Relative to the Rest of the United States ......... 42
B.4. Earnings Differences for Manufacturing Workers, by Demographic Characteristic, Controlling for Education and Occupation (2019 U.S. dollars) .................................................. 42
B.5. Demographics of Ohio Students in Manufacturing-Related Programs Relative to Overall Ohio Student Sample from 2006 to 2019 .................................................. 43
B.6. Industry of Employment After Completing Manufacturing-Related Credential .......................................................... 43
B.7. Industry of Employment After Completing Manufacturing-Related Credential .......................................................... 44
B.8. Median Full-Time Wages for Students in Manufacturing-Related Programs (2021 U.S. dollars) .......................................................... 44
B.9. Median Full-Time Wages for Students in Manufacturing-Related Programs One Year After Completion, by Demographic Characteristic (2021 U.S. dollars) .................................................. 45
B.10. Regression of Full-Time Wages Among Students in Manufacturing-Related Programs, by Degree Type and Industry of Employment, by Race and Gender (2021 U.S. dollars) ............ 45
B.11. Median Full-Time Wages Among Students in Manufacturing-Related Programs, by Degree Type and Industry of Employment (2021 U.S. dollars)........................................ 46
B.12. Demographic Characteristics of Manufacturing Workers Who Pursued Postsecondary Education................................................................. 50
B.13. Demographic Characteristics of Manufacturing Workers Who Pursued Various Types of Postsecondary Education Programs ................................................................. 50
CHAPTER 1

Challenges for the Manufacturing Industry

The manufacturing workforce is shaped by actual and perceived workforce needs. Perceptions of manufacturing careers and industry projections influence who enters manufacturing pathways, and employer demand varies with industry conditions and technological advancements. This chapter discusses historical trends in manufacturing for the United States and Ohio, the composition of the manufacturing workforce, pathways into manufacturing careers, and current challenges facing the industry. It also provides a framework for understanding potential ways in which the manufacturing workforce could be strengthened.

Status of the Manufacturing Industry

The U.S. manufacturing industry is experiencing a resurgence. Although manufacturing employment levels are far below the 1979 peak of 20 million workers, employment recently grew to approximately 13 million workers after dropping during the coronavirus disease 2019 (COVID-19) pandemic, as shown in Figure 1.1 (Harris, 2020; U.S. Bureau of Labor Statistics, 2023). Manufacturing employment had been increasing between 2010 and 2019, before the pandemic drop (U.S. Bureau of Labor Statistics, 2023). As of the first quarter of 2023, manufacturing employment exceeded prepandemic levels. Additional growth in manufacturing employment is projected in the coming years, especially for skilled manufacturing positions (Moutray, 2022).

The recent growth in manufacturing employment reflects broader trends in the expanding U.S. manufacturing industry. The industry is projected to grow in the coming years as the government invests more

FIGURE 1.1
U.S. Manufacturing Employment

NOTE: Data indicate the quarterly count of total manufacturing workers (seasonally adjusted). Shaded areas indicate recessions.
resources into bolstering domestic manufacturing, such as through the recently passed CHIPS and Science Act (Public Law 117-167, 2022). In addition, many U.S. companies are choosing to manufacture more products domestically as a result of supply chain challenges during the COVID-19 pandemic, trade wars, and other geopolitical challenges (Mann, 2022; Schwartz, 2022).

This growth will likely compound existing shortages of manufacturing workers. Currently, the manufacturing industry’s demand for workers outpaces the supply of workers (Giffi et al., 2018). The manufacturing workforce is also aging; one recent study found that those aged 55 or older make up nearly a quarter of the manufacturing workforce (Manufacturing Institute, 2019). In 2018, a Deloitte and Manufacturing Institute report projected that 2.4 million manufacturing jobs may remain unfilled between 2018 and 2028 because of retirements, growth in the sector, and hiring difficulty (Giffi et al., 2018). This is especially true for high-skill manufacturing positions—defined as both traditionally high-skill positions (e.g., machinists, industrial maintenance technicians, welding, and engineering) and positions that now require more technological expertise—which manufacturing employers are now struggling to fill. Worker shortages are likely to grow as the industry expands unless action is taken to increase the pipeline of workers.

Furthermore, the types of workers demanded by the manufacturing industry have drastically shifted over the past few decades with the emergence of new technologies and will continue to shift as the industry becomes increasingly technologically advanced. Companies anticipate that this “fourth industrial revolution” will rely on more digital technologies, automation, and improved production processes (IBM, undated). These changes are a contributing factor for the increased demand for highly skilled workers and represent a growing part of the “skills gap” in manufacturing (Wellener et al., 2021). Some manufacturing employers may also face challenges in recruiting a highly skilled or diverse workforce if there are regional mismatches in the supply and demand of workers, as some recent research has shown exists among lower-skilled employees (Theys et al., 2019).

To address these trends, manufacturing companies are raising wages and other forms of compensation to try to attract new workers (Moutray, 2022). They are also finding ways to retrain or upskill existing workers so that they can fill the more highly skilled positions. However, these companies continue to struggle to identify the talent needed, and many employers are concerned about how they will fill future positions as the industry expands and manufacturing becomes more high-tech. Understanding how best to help potential and existing manufacturing workers retool and reskill is critical to ensuring that these workers are not left behind, as has been the case with other shocks, such as the rise of Chinese exports at the start of the millennium (Autor, Dorn, and Hanson, 2021).

Hiring challenges are further compounded by the industry’s image problems, which can make it tough to attract new workers. First, many people assume that manufacturing is a dying industry with few high-skill, well-paid positions (Deichler, 2021; Suneson, 2018). Second, higher-paid workers in manufacturing are predominantly male and white, and the industry struggles to appear inclusive and focused on prioritizing diversity. Third, many employers and employees note that flexibility and the industry’s frequent shift work is a challenge for employees (National Association of Manufacturers, 2022).

Research is needed to identify promising strategies for expanding the pipeline of highly skilled manufacturing workers and meeting employers’ growing skill demands. While much work has focused on identifying ways to reskill or train workers for these manufacturing positions, much less is known about why people who already have these skills do not enter manufacturing. Among people with manufacturing-related credentials, the most common industries for employment—aside from manufacturing—include administrative support and waste management; transportation and warehousing; and wholesale or retail (Brown et al., 2022).
Challenges to Recruiting a Diverse Manufacturing Workforce

One potential solution to the worker shortage is to find new streams of workers, such as workers from under-represented demographic subgroups. Approximately 30 percent of manufacturing workers are women, despite the fact that women compose a much larger fraction of the total U.S. workforce (U.S. Census Bureau, 2023a; U.S. Department of Commerce, 2021). Additionally, among full-time employees, a larger share (65 percent) of the U.S. manufacturing workforce is non-Hispanic white compared with the share of workers in nonmanufacturing industries (61 percent) (U.S. Census Bureau, 2023a). Moreover, one study found that, among people with credentials in manufacturing, less than half go on to work in the manufacturing industry: 40 percent of white workers, 23 percent of Black workers, and 34 percent of Hispanic workers (Brown et al., 2022).

Furthermore, there are gaps in the types of manufacturing occupations held by people from different racial/ethnic backgrounds and by men and women. Occupational heterogeneity is important because of occupational differences in wages and benefits, working conditions, and career mobility. Some of these occupational differences may contribute to the pay gaps we see in manufacturing: Median earnings for women are approximately 80 percent of those for men (U.S. Census Bureau, 2023a), and Black and Hispanic workers earn approximately 70–74 percent of what white workers earn (U.S. Census Bureau, 2023a). A 2021 Brookings report shows that manufacturing has the largest racial mobility gap of all industries examined: Black and Hispanic workers are less likely than white workers to have upward occupational transitions by 14 to 18 percentage points (Escobari, Seyal, and Contreras, 2021).\(^1\)

These findings highlight that more can be done to bring new sources of talent into the manufacturing industry and support upward career trajectories within the manufacturing industry. For lower-skill workers, entrance into manufacturing from other industries is often associated with wage increases, given that the manufacturing industry tends to pay low-skill workers more than nonmanufacturing industries do. A recent report found that among median-wage, non–college-educated employees, Black and Hispanic workers in manufacturing earn approximately $5,000 more per year than those in nonmanufacturing industries (Scott et al., 2022). Thus, expanding representation in the manufacturing industry could be particularly helpful for Black and Hispanic workers who have historically had lower wages than white workers.\(^2\)

Manufacturing in Ohio

We study manufacturing education and employment in Ohio, which is the fourth-largest state in terms of manufacturing employment (U.S. Census Bureau, 2023a). Figure 1.2 shows the total number of manufacturing employees in Ohio since 2003 (not seasonally adjusted). Similar to the United States as a whole, Ohio experienced a decline in manufacturing jobs in the Great Recession and then saw an increase in manufacturing employment between 2010 and 2020, just before the COVID-19 pandemic. Manufacturing employment bounced back after the COVID-19 pandemic and is close to the prepandemic level.

Currently, there are more than 650,000 manufacturing jobs in Ohio, representing more than $42 billion in payroll as of 2020 (Ohio Manufacturers’ Association, 2022a). The number of manufacturing jobs in Ohio is also expected to grow in future years, especially with major investments from companies such as

\(^1\) The report’s authors define upward transitions as occupational transitions that result in “a higher-than-expected wage increase (compared with the average wage increase for all transitions starting from the same wage level)” (Escobari, Seyal, and Contreras, 2021, p. iii).

\(^2\) Gould (2021) found that the decline of manufacturing employment since the 1960s in the United States has had larger impacts on Black people than on white people. This, in turn, resulted in racial differences in terms of such outcomes as wages, marriage trends, poverty, single-parent status, and death rates.
Intel, Ford, General Motors, and Honda (Haidet, DeNatale, and Fischer, 2022; Intel, 2022; Valdes-Dapena, 2022; White and Shepardson, 2022). For many manufacturing companies, Ohio is an attractive place for investment because of its tax benefits (e.g., the state has no corporate income tax and has a manufacturing sales tax exemption), central location, and high supply of talent (Fastco Works, 2021; Ohio Administrative Code, 2019).

Education as a Pathway for Expanding and Strengthening the Manufacturing Workforce

Education is one potential pathway for strengthening the manufacturing workforce. Ohio has a robust post-secondary sector: There are 14 four-year public universities, 23 two-year community colleges, 49 technical centers, and more than 50 four-year private colleges and universities (Frank LaRose, undated). More than 500,000 students enrolled in Ohio higher educational institutions in fall 2021 (National Student Clearinghouse Research Center, 2021). Roughly 60 percent of enrollments are from students attending one of the 14 four-year public universities (Ohio Department of Higher Education, undated). Ohio Technical Centers (OTCs) are also part of the postsecondary sector; these institutions provide noncredit training across a variety of industries at 49 career centers across Ohio (Ohio Technical Centers, undated).

The state’s universities and community colleges offer credit-bearing certificate, associate degree, and bachelor’s degree programs in applied technical fields, and many offer noncredit training that can help prepare workers to obtain third-party industry-recognized certifications and licenses. The majority of individuals who earn certificates and associate degrees in Ohio do so at community colleges (Daugherty et al.,
Challenges for the Manufacturing Industry

2020), and OTCs also play an important role in providing (noncredit) occupational training and credentials. Credentials at the sub-baccalaureate level are particularly important given that the majority of Ohio’s manufacturing workforce has a sub-baccalaureate education, and these credentials directly support employment opportunities. For example, per data from the Ohio Manufacturers’ Association, to become an advanced welder, an individual would need to obtain a welding-specific certification (e.g., from the American Welding Society or another organization); to be a welder inspector, the individual would need an associate degree (Making Ohio, undated).

Additionally, Ohio is a leader in stackable credentials and other initiatives focused on connecting education programs with worker and employer needs (Daugherty et al., 2020). Stackable credentials enable workers to earn two or more occupation-specific credentials (such as a badge, certificate, or certification) sequentially, and each credential is earned in a short period of time. The sequential nature of these credentials provides students with several entry and exit points, which is particularly beneficial for students who pursue nontraditional educational pathways (Daugherty et al., 2020). Evidence from Daugherty et al. (2023) also suggests that stackable credentials might particularly benefit low-income individuals by narrowing earnings gaps with their higher-income peers. Credentials more broadly are directly beneficial in terms of worker earnings (Bahr et al., 2015; Belfield and Bailey, 2017; Bettinger and Soliz, 2016; Bohn, Jackson, and McConville, 2019). Brown et al. (2022) found that people who earn a manufacturing credential go on to have higher incomes and a greater likelihood of participating in the labor force than similar people who did not earn the credential. In this way, credentials may also be a vehicle for reducing wage disparities for underrepresented groups. While Brown et al. (2022) found that race/ethnicity and gender differences in manufacturing wages and employment persist before and after earning a manufacturing credential, gaps in earnings by race/ethnicity and gender are much narrower post-credential for those employed in manufacturing.

Manufacturing employers are actively participating in the reskilling of their workers. A recent National Association of Manufacturers survey of more than 300 manufacturers, fielded in May 2022, found that about 60 percent of responding employers were creating or expanding internal training programs at their companies, and 50 percent of responding employers stated that they were collaborating with educational institutions on skill certification programs. Ohio also has several education initiatives specifically related to manufacturing. In 2014, Ohio was awarded funding through Trade Adjustment Assistance Community College and Career Training grants from the U.S. Department of Labor to build manufacturing certificate programs. The state then established Ohio TechNet, a consortium of technical centers and colleges and universities that have partnered with the Ohio Manufacturers’ Association and other partners to enhance training and apprenticeship and engage employers (Ohio TechNet, undated). In 2019, Lorain County Community College, in partnership with Ohio TechNet and the Ohio Manufacturers’ Association, received a $12 million award from the U.S. Department of Labor to upskill Ohioans through industry-recognized apprenticeship programs (Lorain County Community College, 2019). More recently, in August 2022, the Ohio Manufacturers’ Association won a $23.5 million workforce grant from the U.S. Economic Development Administration to continue work advancing manufacturing workforce solutions; this includes enrolling 6,000 individuals in training programs to improve the skills of workers seeking or already in manufacturing jobs (Ohio Manufacturers’ Association, 2022b). Given the growing demand for manufacturing workers in Ohio, these initiatives are poised to help address the workforce shortage.

Framework for Understanding Knowledge Gaps

In this report, we examine strategies for drawing more diverse and highly skilled workers into Ohio’s manufacturing industry. Specifically, we examine the following research questions:
1. How does Ohio’s manufacturing industry compare with that of the rest of the United States? (Chapter 2)

2. What is the educational pipeline for Ohio’s manufacturing industry? (Chapter 3)
   a. How do manufacturing-related enrollments and completions vary by type of credential (e.g., certificate, associate degree, bachelor’s degree) and demographic characteristics?
   b. What share of students with manufacturing-related training pursue employment in the manufacturing industry, and how does this differ by credential type and demographic characteristics?
   c. How do wages differ for students who are employed in the manufacturing industry versus those who are not?

3. What is the employment experience of workers in the manufacturing industry? (Chapter 4)
   a. What are wages and retention rates for manufacturing workers?
   b. How do wages and retention in the manufacturing industry differ by demographic characteristics?

4. What are the potential pathways into the manufacturing industry? (Chapter 5)
   a. From where are recent entrants to the manufacturing industry drawn? What are the educational experiences of those who enter directly from education? What are the most common industries from which workers are drawn?
   b. What are the rates of retention and upskilling in this sample?
   c. How do the above patterns differ by demographic characteristics?

5. What are the implications of our findings for stakeholders in Ohio, such as employers and employees in the manufacturing industry and postsecondary educational institutions? (Chapter 6)

The first research question is intended to benchmark Ohio relative to the rest of the United States and highlight the demographic disparities present in Ohio and specifically in Ohio’s manufacturing industry. The second research question is intended to help us understand whether there is a sufficient supply of skilled individuals and to what extent there are disparities by demographic characteristics; the answers to these questions can inform potential policy responses related to attrition from education to employment. The third research question allows us to examine existing workforce characteristics and disparities by demographic characteristics, which can inform our understanding of where the diversity gaps in the workforce are most pronounced and potential reasons for them. The fourth research question is intended to help us understand the potential pathways into manufacturing, with a focus on recent entrants for whom we are able to examine retention and subsequent pursuit of additional education. Examining these factors (as well as differences by demographic characteristics) can inform potential policy responses related to drawing in new sources of workers, retaining them, and upskilling.

In answering these questions, we draw on the framework in Figure 1.3 for understanding entry and exit points for manufacturing. On the left-hand side of the figure, there are several entry points into employment in Ohio manufacturing: from education (manufacturing- or nonmanufacturing-specific), from other industries in Ohio, from employment outside Ohio, and from unemployment or outside the labor force. Throughout our analysis, we focus on both enrollment in education and degrees earned; we analyze enrollments even if they do not necessarily lead to a degree, because many potential manufacturing workers might not complete a degree.\(^3\) We recognize that there are some limitations to looking at enrollment, but we examine

---

\(^3\) Initially enrolling in a manufacturing-related program signals some interest in working in manufacturing, and we think it is important to understand what these students do even if they do not complete a degree. This also seems important because, in many institutions, the majority of students do not complete a degree. Nevertheless, students who enroll in a manufacturing-related program may have less interest in manufacturing than those who complete a degree or may be different in other...
it because it provides a broader view of the full set of individuals interested in pursuing a manufacturing-related career.

On the right-hand side of the figure, there are several pathways out of manufacturing: pursuing additional education or training, working in other (nonmanufacturing) industries, leaving Ohio (e.g., working in another state), becoming unemployed, or exiting the labor force entirely.

We also present factors that influence the inflow and outflow of workers in the manufacturing industry, which we discuss in this report. These factors include interest in working in the industry, perceptions of the industry (e.g., perceptions about safety), pay, workplace benefits, diversity and representation in the industry (e.g., limited representation of certain demographic groups could influence retention), employer demand, and retirement.

Summary

This chapter highlights the manufacturing industry’s challenges with regard to worker shortages and improving diversity in the industry. While employers and postsecondary institutions in Ohio have implemented useful initiatives, more work can be done to understand the attrition points to bolster the supply of talent and determine how best to retain and upskill workers. Next, we examine in more depth how the Ohio manufacturing workforce compares with the U.S. manufacturing workforce, and the subsequent chapters delve more into understanding the attrition points and implications for strengthening Ohio’s manufacturing workforce.

Important ways. In addition, enrollment data are not always reliably estimated (because of incentives by educational institutions to inflate enrollment numbers for federal funding purposes).
CHAPTER 2

Education, Earnings, and Career Trajectories of Manufacturing Workers in Ohio and the Rest of the United States

In this chapter, we examine how the manufacturing workforce in Ohio compares with the U.S. workforce from 2005 to 2019 in terms of demographics and wages. Understanding how Ohio compares with the rest of the country is important for determining the broader applicability of our Ohio-specific findings to the rest of the United States. Understanding the workforce disparities that exist within Ohio also informs the focal subgroups for our Ohio-specific analyses.

We conduct these analyses using publicly available data from the American Community Survey (ACS) (U.S. Census Bureau, 2023a), which is a nationally representative survey that provides information on employment, earnings, education, and other social and economic indicators (additional details on the data and methods employed are provided in Appendix A). Prior research shows that measures of wages and salaries for manufacturing workers vary depending on the data source, the sample, and the way earnings are constructed (Nicholson and Powers, 2015). We use the ACS because it represents the largest publicly available sample of U.S. workers and reflects data on both workers and their demographic characteristics, allowing for analysis along these dimensions. Importantly, we restrict the sample to full-time, working-age individuals (individuals aged 18 to 64 working at least 40 hours per week and 40 weeks per year), and we analyze their annual salaries (as opposed to their hourly or weekly salaries); these restrictions are important because we are interested in how earnings in the manufacturing industry compare with earnings from other types of full-time jobs.

Characteristics of Manufacturing Workers in Ohio Versus the Rest of the United States

As of 2019, ACS data indicate that more than 20 percent of workers in Ohio were employed in the manufacturing industry, making Ohio among the top five states in terms of the state’s share of manufacturing workers (see Table B.1 in Appendix B). Table 2.1 shows that manufacturing workers in Ohio in 2019 were more likely

---

1 We use the five-year ACS files to examine trends in wages and the one-year 2019 file to examine the latest point-in-time estimates for demographic characteristics; we use 2019 data (as opposed to data from later years) in order to avoid issues that occurred with data collection during the COVID-19 pandemic. Standard earnings adjustments include multiplying top-coded wages by 1.5 and removing workers who earned below the federal hourly minimum wage (assuming 2,080 hours worked per year). All earnings are presented in 2019 dollars.

2 This is in contrast to establishment-based surveys, which do not provide demographic information, and the Current Population Survey, which does have demographic information, as well as information on industry licenses and certifications, but has a smaller sample size than the ACS.
to be white; less likely to be Black, Hispanic, or Asian; and more likely to be citizens than were manufacturing workers in the rest of the United States. (All of these differences are significant.) These patterns are reflective of general differences between Ohio and the rest of the United States, as the same differences exist for the nonmanufacturing industry. However, Ohio manufacturing workers are significantly less likely than manufacturing workers in other states to have a four-year college degree (25 percent in Ohio versus 31 percent in the rest of the United States). This could reflect some potential for upskilling in the Ohio manufacturing workforce and/or signal a preference among Ohio employers for experience and industry credentials over college credentials.

There are additional disparities by race/ethnicity and gender when we examine the occupations of manufacturing workers in Ohio (shown in Table B.2 in Appendix B). Black and Hispanic workers are more likely than white workers to hold occupations in transportation and material moving, and women are more likely than men to be employed in office and administrative support roles. These patterns are similar to those of manufacturing in the rest of the United States.

nonmanufacturing refers to all industries except manufacturing. See Appendix A for more details.

We focus on Black and Hispanic workers, since these are the largest minority groups in Ohio.
Earnings of Manufacturing Workers in Ohio Versus the Rest of the United States

Next, we use the ACS data to examine how median annual earnings differ for full-time manufacturing and nonmanufacturing workers in Ohio and the rest of the United States by demographic group. Table 2.2 presents median annual earnings over the 2005–2019 period (in 2019 dollars). (Analyses not presented indicate that earnings have been relatively stable over this period.)

As shown in the table, white workers have a higher median annual income than Black or Hispanic workers. This is true both within Ohio and in the rest of the United States. Male workers also have a higher median annual income than female workers within Ohio and the rest of the United States. In terms of educational attainment, wages are higher for people with higher degrees, with the largest differences in wages for workers who have a bachelor’s degree or higher. In terms of age, older individuals are more likely to earn higher wages, which aligns with these workers having more labor market experience. These patterns are stable over time.

We can also look at the share of people from different demographic groups. The average share of workers in each demographic group over the 2005–2019 period is shown in Table B.3, in Appendix B. The results are similar to Table 2.1: In the manufacturing industry, there are fewer workers from underrepresented minority backgrounds, fewer female workers, relatively more sub-baccalaureate degree holders, and relatively more older workers. These patterns are also stable over time.

Finally, we examine whether earnings disparities could be due to educational and occupational differences. To explore this, we ran a regression that controlled for occupation and educational attainment, as well

### TABLE 2.2
Manufacturing Median Annual Income (2019 U.S. dollars), by Demographic Group

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Rest of United States</th>
<th>Ohio</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>$57,702</td>
<td>$51,797</td>
</tr>
<tr>
<td>Black</td>
<td>$41,039</td>
<td>$41,556</td>
</tr>
<tr>
<td>Hispanic</td>
<td>$35,639</td>
<td>$39,009</td>
</tr>
<tr>
<td>Male</td>
<td>$55,727</td>
<td>$53,955</td>
</tr>
<tr>
<td>Female</td>
<td>$42,656</td>
<td>$41,556</td>
</tr>
<tr>
<td>High school or less</td>
<td>$40,563</td>
<td>$42,934</td>
</tr>
<tr>
<td>One year of college, no degree</td>
<td>$51,051</td>
<td>$50,718</td>
</tr>
<tr>
<td>Associate degree</td>
<td>$55,996</td>
<td>$53,960</td>
</tr>
<tr>
<td>Bachelor’s degree or higher</td>
<td>$94,735</td>
<td>$86,393</td>
</tr>
<tr>
<td>Under 40 years</td>
<td>$44,376</td>
<td>$43,153</td>
</tr>
<tr>
<td>40 years or over</td>
<td>$57,193</td>
<td>$54,978</td>
</tr>
</tbody>
</table>

NOTE: This table reflects the median annual income from 2005 to 2019 for manufacturing workers for the given demographic group. We restricted the sample to full-time, working-age individuals (individuals aged 18 to 64 working at least 40 hours per week and 40 weeks per year). See Appendix A for more details about the sample.

---

5 Nonmanufacturing workers represent both public- and private-sector workers, though the results are similar when we subset to just private-sector nonmanufacturing workers. We use median measures of pay instead of the average to reduce the effect of earnings outliers.

6 There are fewer Black and Hispanic workers in Ohio manufacturing, so the earnings series is more volatile.
as gender, race/ethnicity, year fixed effects, and state fixed effects (for the “Rest of United States” sample), shown in Table B.4, in Appendix B. In line with the graphical patterns above, we see that female workers earn less than male workers, Black and Hispanic workers earn less than white workers, and all educational groups earn less than the college-educated individuals. Thus, occupational differences do not fully explain wage gaps by gender or race/ethnicity.

Summary

These analyses show some similarities between manufacturing workers in Ohio and the rest of the United States. Within manufacturing, white workers tend to earn more than workers from racial/ethnic minority backgrounds, and male workers earn more than female workers. Moreover, female workers within manufacturing are similarly underrepresented in both Ohio and the rest of the United States. This suggests that many of our Ohio-specific findings, presented in the following chapters, are likely to be of value to workers and employers across the United States. Nevertheless, Ohio has a higher share of white workers than the rest of the United States, and, correspondingly, so does the manufacturing industry within Ohio. This suggests that increasing representation of workers from racial minority groups in the manufacturing industry would require a greater regional effort (beyond a single employer or educational program).
CHAPTER 3

Manufacturing-Related Education in Ohio

In this chapter, we examine the demographic diversity and skills of students in the educational pipeline into Ohio’s manufacturing industry. To do this, we examine manufacturing-related enrollment in postsecondary institutions and credential completions, as well as students’ employment outcomes in terms of entrance into the manufacturing industry and wages. We also explore how these patterns differ by demographic characteristics, as well as how employment patterns differ by the density of manufacturing employers within a given region. These analyses are important because they can inform potential policy responses related to attrition from manufacturing-related education to employment.

Ohio Higher Education and Employment Data

For these analyses, we use individual-level data on education and employment records from the Ohio Longitudinal Data Archive (OLDA). These data cover information on enrollments in Ohio’s public higher educational institutions and credential completions at Ohio’s community colleges and four-year colleges. We also have data on enrollments and course completions at the OTCs, which offer noncredit training and certifications aligned to specific industry needs. Because of data limitations, we are unable to study certificate enrollments. In addition, we are unable to study certifications at the OTCs, so we instead focus on course-level enrollments and completions at the OTCs. Finally, we exclude the Ohio Community School System, the single largest OTC, given that its mission is to serve correctional institutions and, thus, it represents training for a very different population of individuals.

Given our data sources, we focus on two types of outcomes: (1) enrollment, which includes data on where students enroll, dates of enrollment, and programs of study, and (2) credentials earned, specifically OTC course completions, certificates, associate degrees and bachelor’s degrees. Certificates and associate degrees may be earned from either community colleges or four-year colleges, while bachelor’s degrees are typically earned at four-year colleges. Our data do not contain information on credentials earned from private institutions or other types of organizations that may offer industry certifications (e.g., non–Title IV institutions). Thus, our analyses will understate manufacturing education in Ohio.

For our analyses on enrollments and credentials earned, our sample reflects all students in public postsecondary education in Ohio who enrolled in or completed a manufacturing-related program from 2006 to 2019. We limit our examination of OTC data to the 2013–2019 period, since records are not reliable over the earlier period (pre-2013). For our analyses on the employment outcomes of students in manufacturing-related programs, we link the education records to employment data over the 2007 to 2021 period. The employment data come from Ohio’s unemployment insurance records, which contain information on work-

---

1 Enrollments describe a student’s institution and program of study. Program of study is defined for all enrollment spells.

2 Enrollments in certificate programs are not included. Data on field of study for postsecondary enrollments are available only beginning in 2006, so most of our analyses focus on 2006–2019.
ers’ quarterly wages and industries of employment for workers employed.³ Additional details regarding the data are described in Appendix A.

An important part of the analysis is our examination of “manufacturing-related” programs. To determine what programs qualify as manufacturing-related, we use the Classification of Instructional Programs (CIP) code associated with a student’s program of study or degree. The CIP code is a national taxonomy of academic programs. Our primary set of results is based on the following definition of manufacturing-related programs: CIP code 15 (engineering technologies and technicians), CIP code 48 (precision production), and seven manufacturing-related CIP codes within CIP code 14 (engineering): mechanical engineering (14.19), electrical and electronics engineering (14.10), industrial engineering (14.35), materials engineering (14.18), construction engineering (14.33), manufacturing engineering (14.36), and polymer/plastics engineering (14.32). (See Appendix A for a detailed discussion of how we selected this subset of CIP code 14). We refer to these throughout the report as manufacturing-related credentials or programs. While this is our best estimate of students with manufacturing-related skills, it does not perfectly capture student intentions about the industry in which they want to work, so it should be viewed as a proxy for manufacturing-focused students.

Overall Trends in Manufacturing-Related Enrollments and Completions

In 2019, more than 30,000 students were enrolled in manufacturing-related programs in Ohio. This number reflects approximately 1,600 students enrolled in OTCs, approximately 13,500 students enrolled in manufacturing-related associate degree programs, and approximately 13,800 students enrolled in manufacturing-related bachelor’s degree programs. Panel A of Figure 3.1 shows that there has been an increase in enrollment in four-year manufacturing-related bachelor’s degree programs and, conversely, a decline in enrollment in manufacturing-related associate degree programs.

In terms of completions, approximately 7,700 students earned a manufacturing-related credential in 2019, with the largest share earning a bachelor’s degree, reflecting a steady increase in bachelor’s degree holders over time. Panel B of Figure 3.1 shows that the number of OTC course completions increased from 2014 to 2016. The number of student completions from manufacturing-related associate degree programs has been stable over time, while there has been an increase in manufacturing-related certificate completions.

Next, we examine differences in the types of educational institutions that students attend, by gender, race, and ethnicity. As shown in Table 3.1, in 2019, manufacturing-related credentials were disproportionately earned by men and white individuals. However, a growing number of female and Asian students have been earning bachelor’s degrees in manufacturing-related fields, which has contributed to female and Asian students making up a larger share of those earning manufacturing-related credentials over time. As of 2019, female and Asian students were more likely to enroll in bachelor’s degree programs than in sub-baccalaureate programs. Conversely, as of 2019, Black students were more likely to enroll in associate degree programs than to enroll in bachelor’s degree programs, a pattern that has been consistent over our sample period. This is partially by design, as short-term credentials and stackable credentials are partially designed to provide more on-ramps into college and opportunities to earn credentials for populations that have historically been shut out of degree programs. These patterns are relevant for understanding diversity within the educational pipeline, especially as higher-level credentials are generally associated with higher pay and advancement within manufacturing.

³ This does not include any information on jobs outside Ohio or jobs that are not covered by the state’s unemployment insurance system, including federal jobs and self-employment.
Table B.5 (in Appendix B) also summarizes how the demographics of students in manufacturing-related programs compare with the overall sample of students in Ohio’s public higher educational institutions. Students in manufacturing-related programs are more likely to be male than the average student in Ohio’s postsecondary education programs. Students in manufacturing-related programs are also more likely to be white than the average student in Ohio’s programs. Student ages also vary across the programs: Students in manufacturing-related programs in the OTCs and associate degree programs are, on average, older than students in OTC or associate degree programs, while students in manufacturing-related bachelor’s degree programs tend to be younger than the average bachelor’s degree student. Thus, expanding the diversity of students within manufacturing-related education programs may be an important step for expanding diversity within the manufacturing workforce.
Industries of Employment of Students in Manufacturing-Related Programs

Next, we used the linked subsample of education records and employment records from 2006 to 2019 to examine the employment outcomes of students with a manufacturing-related credential (both full-time and part-time workers). This analysis is important for understanding the pipeline of highly skilled individuals available to enter the manufacturing industry in Ohio and the extent to which some of these students pursue nonmanufacturing industries. Understanding the types of jobs that students pursue instead of manufacturing may also be helpful for uncovering the reasons students do not enter manufacturing (e.g., wages) or potential ways to attract more students.

Table 3.2 shows that a high share of people who completed a manufacturing-related credential or an OTC course at a public Ohio institution were employed in Ohio one year later: 82 percent of those who completed an OTC course, 84 percent of those who completed a certificate, 83 percent of those who completed an associate degree, and 65 percent of those who completed a bachelor’s degree. However, a much smaller share of people with manufacturing-related credentials are primarily employed in the manufacturing industry in Ohio one year after completing their credentials: 38 percent of those with an OTC course completion, 27 percent of those with a certificate, 25 percent of those with an associate degree, and 30 percent of those

<table>
<thead>
<tr>
<th>Employment and Credential Type</th>
<th>Employed in Ohio</th>
<th>Percentage Employed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One Year After Credential</td>
<td>Three Years After Credential</td>
</tr>
<tr>
<td>Employed in Ohio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OTC</td>
<td>82%</td>
<td>78%</td>
</tr>
<tr>
<td>Certificate</td>
<td>84%</td>
<td>81%</td>
</tr>
<tr>
<td>A.A.</td>
<td>83%</td>
<td>80%</td>
</tr>
<tr>
<td>B.A.</td>
<td>65%</td>
<td>62%</td>
</tr>
<tr>
<td>Employed in manufacturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OTC</td>
<td>38%</td>
<td>36%</td>
</tr>
<tr>
<td>Certificate</td>
<td>27%</td>
<td>26%</td>
</tr>
<tr>
<td>A.A.</td>
<td>25%</td>
<td>26%</td>
</tr>
<tr>
<td>B.A.</td>
<td>30%</td>
<td>29%</td>
</tr>
</tbody>
</table>

SOURCE: Features data from OLDA linked to data on industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance from 2006 to 2021 (CHRR at The Ohio State University, undated).

NOTE: See Appendix A for more information on this sample.

---

4 We are not able to examine employment outcomes for individuals who start an employment spell after the sample period of our data.

For full-time status, we used a proxy: whether workers’ annual earnings were at least the minimum wage in Ohio in the given year times 2,080 hours of work (assuming 40 hours per week and 52 weeks per year). This implies that a full-time worker in Ohio in 2021 was earning at least $18,304 per year ($8.80 per hour x 2,080 hours).

5 We define employment in manufacturing as working in the two-digit manufacturing industry, defined by the North American Industry Classification System.
with a bachelor’s degree were employed in Ohio manufacturing. These rates are relatively stable if we look three or five years after credential completion. Note that we are not able to separate whether it is the credential itself (the earning of a bachelor’s degree) or the selection into the credential (the types of individuals who decide to earn bachelor’s degrees) that drives attrition rates.

These analyses highlight that, while manufacturing is the most common industry in which people with a manufacturing-related credential work after completing their education, there are a significant number of individuals with manufacturing-related training who pursue employment in other industries. Some of these industries, shown in Table B.6 (in Appendix B), are construction; retail trade; professional, scientific, and technical services; administrative and support and waste management and remediation services (ASWMRS); and wholesale trade. (Note that these represent some, though not all, of the industries that workers frequently enter from manufacturing.) People with manufacturing-related sub-baccalaureate degrees, particularly those completing OTC courses or certificates, are likely to work in construction, retail trade, and ASWMRS, while those with bachelor’s degrees are likely to work in professional, scientific, and technical services.

There are also significant differences in entrance rates into manufacturing by race/ethnicity and gender, shown in Table 3.3. (Note that this table abstracts from the specific credential earned.) Among people with any type of manufacturing-related credential (e.g., OTC, certificate, associate degree, or bachelor’s degree), men are more likely to be employed in Ohio one year after completing a degree than women are (76 percent relative to 70 percent, shown in column 1). Men are also more likely than women to be employed in manufacturing (29 percent versus 22 percent, shown in column 2), and this difference is not fully explained by overall employment rates (38 percent versus 31 percent, shown in column 3). In terms of race/ethnicity, white individuals with a manufacturing-related credential are more likely to be employed in manufacturing than people of color with a manufacturing-related credential (29 percent versus 22 percent, shown in column 2), and this persists even after conditioning on employment in Ohio. These racial/ethnic gaps are primarily

### TABLE 3.3
Attrition from Manufacturing-Related Education to Manufacturing Employment, by Demographic Group

<table>
<thead>
<tr>
<th></th>
<th>Share Employed in Ohio</th>
<th>Share Employed in Ohio Manufacturing</th>
<th>Conditional on Ohio Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td>All manufacturing students</td>
<td>75%</td>
<td>28%</td>
<td>37%</td>
</tr>
<tr>
<td>Male</td>
<td>76%</td>
<td>29%</td>
<td>38%</td>
</tr>
<tr>
<td>Female</td>
<td>70%</td>
<td>22%</td>
<td>31%</td>
</tr>
<tr>
<td>White</td>
<td>77%</td>
<td>29%</td>
<td>38%</td>
</tr>
<tr>
<td>Non-white</td>
<td>69%</td>
<td>22%</td>
<td>32%</td>
</tr>
<tr>
<td>Black</td>
<td>75%</td>
<td>20%</td>
<td>27%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>74%</td>
<td>29%</td>
<td>39%</td>
</tr>
<tr>
<td>Asian</td>
<td>54%</td>
<td>19%</td>
<td>36%</td>
</tr>
</tbody>
</table>

**SOURCE:** Features data from OLDA linked to data on quarterly wages and industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance from 2006 to 2021 (CHRR at The Ohio State University, undated).

**NOTE:** See Appendix A for more information on this sample.

---

Among people who are employed in Ohio, recipients of manufacturing-related bachelor’s degrees are more likely than individuals with shorter manufacturing-related credentials to work in manufacturing. However, those with bachelor’s degrees are the least likely to appear in the Ohio workforce data. This may be because individuals with bachelor’s degrees are generally more likely to leave the state (Foote and Stange, 2022).
driven by Black students in manufacturing-related programs, who are the least likely to be employed in manufacturing in Ohio, even after conditioning on employment.

Table B.7 (Appendix B) presents the different industries of employment for individuals with a manufacturing credential by gender and race/ethnicity one year after completion. Although there are some differences in terms of the share employed in each industry by gender and race/ethnicity, the patterns do not suggest that employment in particular industries is driving the gender or racial employment gap.

The local labor market may partly influence the education-to-employment attrition. When we examine geographic differences, we see that there is lower attrition from manufacturing-related education to manufacturing employment in counties where there is a greater density of manufacturing employers (defined as a higher number of manufacturing establishments per 1,000 people) (shown in Figure B.1). This suggests that the local labor market, particularly the presence of local manufacturing jobs, may be related to the observed drop-off from education to employment.

**Manufacturing Students’ Wages**

An important component of understanding the education-to-employment pipeline is understanding the wages that students in manufacturing-related programs receive in the labor market, as a whole and for specific subgroups. We restrict these analyses to full-time earnings, as we are interested in what full-time employment in the industry offers. We begin by summarizing the median wages (in 2021 U.S. dollars) for each type of manufacturing-related credential—irrespective of industry of employment—one, three, and five years after completion in Table B.8 (Appendix B). In line with the ACS analysis in Chapter 2, we find that more highly educated workers receive higher wages. Table B.9 presents the median wage one year after credential completion, separately by workers’ gender and race; we find that male and white workers receive higher wages than their non-male, non-white counterparts at each education level. We also find similar patterns when we conduct regression analyses to examine how gender wage gaps and racial wage gaps vary by credential and whether workers are employed in the manufacturing industry. Table B.10 shows that both female students with manufacturing-related credentials and Black students with manufacturing-related credentials earn significantly less than their counterparts across nearly all credential groups (the first five columns) and when we restrict the sample to those working in the manufacturing industry one year after earning a credential conditional on educational attainment (the last column). (The exception to this are female students with an OTC course completion; in this case, we do not see significant differences.) This suggests that, in general, certain demographic groups experience persistently lower wages than their peers regardless of educational background. These gaps persist even for those working in the manufacturing industry, though the gender wage gap is smaller for those working in manufacturing (indicating that industry sorting may drive some of the gender wage gap).

We also examine differences in wages for students who enter manufacturing and those who enter other industries to understand whether wages may drive sorting to different industries. As shown in Figure 3.2 and Table B.11, students with a manufacturing-related credential who enter manufacturing in their first year after completing a credential earn higher wages than students (with a manufacturing-related credential) who enter other industries; this holds within demographic subgroups (e.g., Black students in manufacturing-related programs, who are the least likely to be employed in manufacturing in Ohio, even after conditioning on employment.

---

7. This analysis restricts the sample of manufacturing employers to those whose establishments are all in the same county; thus, it does not capture workers who work at multi-establishment employers whose establishments are located across multiple counties.

8. The results are not materially different when we include part-time workers.
FIGURE 3.2
Median Wages Among Manufacturing Students One Year After Finishing Credential, by Credential Type and Industry of Employment

(A) Employed in manufacturing

(B) Employed in non-manufacturing industry

SOURCE: Features data from Ohio higher educational records linked to data on quarterly wages and industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance from 2006 to 2019.

NOTE: See Appendix A for more information on this sample.
programs earn more in the manufacturing industry than in a nonmanufacturing industry). Among students with an associate degree or certificate, the wage gap between those entering manufacturing and those entering other industries is over $8,000 in their first year of employment, and a wage gap is still present five years later, suggesting that students in manufacturing-related programs are not likely to be drawn to other industries because of better wages. Thus, students with manufacturing-related credentials may work in nonmanufacturing industries for nonwage reasons (e.g., preferences about nonwage amenities, employer preferences and job openings, or skills mismatches).

Summary

The above results highlight demographic disparities in the education pathways of potential manufacturing workers. Expanding demographic diversity in manufacturing-related programs may be important for expanding diversity in the manufacturing workforce. Additionally, while there is a significant supply of students in manufacturing-related programs, a large share of students do not work in manufacturing after completing their degrees. This attrition does not appear to be driven by industry pay gaps, as the manufacturing industry pays higher wages than other industries do. However, pay discrepancies within the manufacturing industry still exist between minority (e.g., female, non-white) and nonminority individuals.
CHAPTER 4

Manufacturing Workers in Ohio

Next, we build on the prior chapter’s examination of the educational pipeline into the manufacturing industry by examining the manufacturing workforce more broadly using data on all Ohio workers in jobs covered by the state’s unemployment insurance system between 2003 and 2021. These analyses are intended to examine labor market outcomes for a broader set of manufacturing workers (i.e., not just those who completed higher education from 2006 to 2019). Thus, these analyses can inform our understanding of existing manufacturing workforce characteristics, attrition rates, and challenges in building a diverse workforce.

Ohio Employment Data

For this analysis, we leverage the state’s quarterly wage data from its unemployment insurance system (described in Chapter 3) and make a few restrictions to construct the workforce sample. We define manufacturing workers (in a given year) as those for whom manufacturing was the industry in which they earned the most income in the calendar year. When we examine wages, we focus on full-time earnings, because we are primarily interested in understanding how earnings in the manufacturing industry compare with earnings in other types of full-time jobs.1 Because our employment data do not have a measure of hours worked, we use a proxy for full-time status: whether workers’ annual earnings were at least the minimum wage in Ohio in the given year times 2,080 hours of work (assuming 40 hours per week and 52 weeks per year). In 2021, this implies that a full-time worker in Ohio was earning at least $18,304 per year ($8.80 per hour x 2,080 hours). We refer to these workers as full time for simplicity but recognize that some people who work less than full time will be included in this sample (which is a limitation of our data). Another limitation of the employment data is that they do not include information on workers’ race or ethnicity; thus, while we are able to look at differences in our results by gender and age, we are not able to examine patterns by race or ethnicity.

When we examine worker wages, we use the full sample of observations in the data (all manufacturing full-time workers in jobs between 2003 and 2021 covered by Ohio’s unemployment insurance system). However, when we examine retention three and six years later, we examine the sample of manufacturing workers who were full time in 2013, and we do not restrict them to being full time in subsequent years; we do this because we are interested in following a cohort of full-time manufacturing workers for whom we can observe the full set of later-stage employment outcomes.

---

1 In addition, the national estimates presented in Chapter 2 are based on full-time workers. The Ohio data do not contain information on hours worked, so we use this benchmark as a proxy for likely full-time employment.
Manufacturing Workers’ Wages

Figure 4.1 summarizes the Ohio manufacturing workforce over time. The total number of full-time employees was highest in the years prior to the Great Recession (nearly 800,000 workers), dipped in the years following the Great Recession, and then stayed nominally stable at approximately 665,000 full-time workers in 2021. In 2021, median wages were approximately $52,000 (in 2021 dollars), and this has been mostly stable over time. In terms of demographic characteristics, about 26 percent of manufacturing workers were female in 2021, and this share has been relatively constant over time. The average age of the manufacturing workforce was approximately 44 years over this period.

Figure 4.2 summarizes the number of manufacturing workers and median wages by gender, and Figure 4.3 summarizes them by age. In 2021, median wages were about 25 percent higher for men than for women in manufacturing and about 22 percent higher for older workers (aged 40 and over) than for younger workers (below 40). The gender wage gap aligns with female workers earning less than male workers in both the ACS analysis in Chapter 2 and the sample of students in manufacturing-related programs in Chapter 3.

Manufacturing Workers’ Retention

Next, we examine retention in Ohio’s manufacturing industry. Among full-time manufacturing workers in 2013, 77 percent were still employed (full time or part time) in manufacturing in 2016, and 63 percent were still employed (full time or part time) in manufacturing in 2019.\(^2\) Figure 4.4 summarizes the paths of the Ohio workers who leave manufacturing (the residual 23 percent in 2016 and 37 percent in 2019). The most common path, represented by the gray portion of each bar in the figure, is exiting the full-time Ohio manufacturing workforce entirely: 14 percent of manufacturing workers in 2013 exited by 2016, and 25 percent exited by 2019. This share comprises two groups. The first consists of individuals who work part time in another industry, become unemployed, or exit the labor force entirely. The second group consists of indi-

---

\(^2\) In 2016, 74 percent were employed full time (and 3 percent were employed part time); in 2019, 60 percent were employed full time (and 3 percent were employed part time).
FIGURE 4.2
Number of Full-Time Manufacturing Workers and Median Wages, by Gender

(A) Number of manufacturing workers

(B) Median wages

SOURCE: Features OLDA data from quarterly wages and industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance from 2003 to 2021 (CHRR at The Ohio State University, undated).
NOTE: See Appendix A for more information on this sample. Wages are in 2021 dollars.

FIGURE 4.3
Number of Full-Time Manufacturing Workers and Median Wages, by Age

(A) Number of manufacturing workers

(B) Median wages

SOURCE: Features OLDA data from quarterly wages and industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance from 2003 to 2021 (CHRR at The Ohio State University, undated).
NOTE: See Appendix A for more information on this sample. Age over 40 refers to workers aged 40 and over. Wages are in 2021 dollars.
individuals whom we are not able to capture in our data but who are still working, specifically those who become employed outside Ohio or become federally or self-employed. Thus, we are not able to distinguish between these two types of leavers.

The blue portion of each bar in the figure represents the workers who remain employed in Ohio but move to another, nonmanufacturing industry; among full-time manufacturing workers in 2013, roughly 9 percent were employed in another industry three years later (in 2016), and 12 percent were employed in another industry six years later (in 2019). Workers who chose this path frequently left manufacturing to work in retail trade; wholesale trade; construction; professional, scientific, and technical services; and ASWMRS. (Note that these represent some, though not all, of the industries that workers enter when they leave manufacturing.) Figure 4.4 also presents gender and age differences in this pattern: Women were significantly more likely than men to leave manufacturing for another industry in Ohio, and younger workers were significantly more likely than older workers to leave manufacturing for another industry in Ohio.

To understand whether some of this attrition is driven by industry pay, we examine the earnings of these individuals before and after they switched industries. Workers with lower manufacturing wages were more likely than those with higher manufacturing wages to switch industries, as shown in Figure B.2, which presents the median wages of switchers and stayers in 2013 employed full time in manufacturing. Workers who switched to full-time employment in another industry earned only slightly higher wages in the first year

3 Additional Ohio-specific data on net migration, rates of unemployment, self-employment, and the size of the labor force would be necessary to determine the relative shares of each group.
in the new industry; wages then increased more in the second year (shown in panel A of Figure B.2). Over the long term (panel B), workers who switched to full-time employment in another industry had wages that were over $2,200 higher six years later (in 2019) than those of workers who stayed in manufacturing. When we examine differences by gender, we see that women who left manufacturing had wages similar to those of women who stayed in manufacturing, while men who switched out of manufacturing had lower manufacturing wages to begin with (i.e., in 2013, the base year) than the stayers. Lower-wage workers may be more likely to switch industries if they have fewer manufacturing-specific skills than the higher-wage workers do or if other industries offer higher wages.

Summary

The above results highlight that the median wages of manufacturing workers have been fairly stable in recent years, as have the gender composition of the workforce and gender disparities in wages. In addition, retention appears to be a challenge for an important portion of the manufacturing workforce; while some of this is due to workers exiting the Ohio full-time labor market, other workers are choosing to leave manufacturing for another industry in Ohio (12 percent in 2019). Attrition is higher for women than for men, but women do not appear to be leaving for higher pay in other industries. Thus, within-manufacturing earnings inequality and nonwage factors may be influencing attrition rates among women.
CHAPTER 5

Pathways into Manufacturing for Recent Entrants

Next, we build on the prior chapter’s examination of workforce patterns by combining the education data with the employment data. More specifically, we examine potential pathways into the manufacturing industry using Ohio higher education and employment data. As discussed in Chapter 1, there are many entry points into manufacturing, including from education, other industries, unemployment, outside the labor force, and working outside Ohio. We focus on recent entrants who first entered the Ohio workforce between 2007 and 2013 because this is the sample for whom we can best link wage and education records and because this group represents younger workers for whom policy changes are likely to be particularly meaningful. For example, understanding how many recent entrants are coming from other industries is useful for determining additional sources of potential manufacturing workers. This chapter focuses on characterizing these pathways and differences by demographic characteristics. We also examine the existing state of retention and upskilling to understand the challenges and opportunities faced by the manufacturing industry and different demographic groups.

Recent Entrants

We define recent entrants as workers who first entered the Ohio workforce (but not necessarily manufacturing) between 2007 and 2013; we are not able to include individuals who entered the workforce later than 2013 because of some data limitations discussed in Appendix A.1

We make two additional sample restrictions for subsets of our analyses. First, when we examine pathways into manufacturing over the period from 2006–2007 to 2019 (since 2006 for the education data and since 2007 for the employment data), we restrict our analysis to the subsample of recent entrants working full time or part time in manufacturing in 2019; we include part-time workers to broadly identify the potential pathways into manufacturing. Second, when we assess recent entrants’ retention and upskilling outcomes over the 2013–2019 period, we restrict the sample to the subsample of individuals working full time in manufacturing in 2013, as we are interested in the experiences of a full-time cohort and we need to be able to follow them for several years. We then examine their subsequent education and labor market (full-time or part-time) experiences.2

1 These years maximize the match rate between the educational and workforce records because of the following limitations of the data. First, from 2003 to 2005, we were not able to match records to CIP codes, which means that we cannot identify individuals with manufacturing training over this period. Second, we are missing important identification numbers for many OTC students starting in 2014, which reduces the extent to which we can match OTC education records to workforce records. Finally, there is a lower match rate between the education records and employment records for those who first entered the Ohio workforce before 2007 and after 2013.

2 We examine both full-time and part-time workers because we want to understand the full set of career paths these workers take.
These samples are different from the ones used in Chapter 3, which represent the broadest pipeline of students in manufacturing-related programs, and the ones used in Chapter 4, which represent the broadest group of manufacturing workers. Instead, these samples focus on recent entrants to Ohio’s workforce for whom we are able to observe pathways into manufacturing (including from education) and retention and upskilling outcomes.

Finally, when we examine education experiences for this sample, our measures of education are a proxy for true educational background. This is because we can capture educational experiences only from 2006 to 2019 in Ohio’s public higher educational institutions. Workers who received their education at a postsecondary institution outside Ohio, at a private or non–Title IV institution, or before 2006 are grouped with those who have no educational credentials. In addition, our data likely underestimate the number of students who pursued a certificate in a manufacturing-related program. Because of these limitations, we do not specifically examine pathways from certificate programs to the workforce. However, we include information on certificate enrollments, where available, in the overall rate of manufacturing-related education when examining the rate at which workers pursue postsecondary education.

### Potential Avenues into the Manufacturing Industry

We begin by examining the common pathways into Ohio’s manufacturing workforce for the sample of recent entrants who were full-time or part-time manufacturing workers in 2019. Table 5.1 summarizes the share of workers who enter directly from an Ohio postsecondary program,\(^3\) from another industry in Ohio, or from

<table>
<thead>
<tr>
<th>Pathway into Ohio Manufacturing Workforce</th>
<th>All</th>
<th>Male</th>
<th>Female</th>
<th>Older</th>
<th>Younger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coming from another industry</td>
<td>63.9%</td>
<td>64.3%</td>
<td>68.2%</td>
<td>49.3%</td>
<td>68.6%</td>
</tr>
<tr>
<td>Top industry</td>
<td>24.8%</td>
<td>25.4%</td>
<td>24.7%</td>
<td>22.4%</td>
<td>25.6%</td>
</tr>
<tr>
<td>Second-highest industry</td>
<td>9.1%</td>
<td>9.0%</td>
<td>10.4%</td>
<td>5.1%</td>
<td>10.6%</td>
</tr>
<tr>
<td>Third-highest industry</td>
<td>7.9%</td>
<td>7.3%</td>
<td>10.3%</td>
<td>4.4%</td>
<td>9.6%</td>
</tr>
<tr>
<td>Coming from postsecondary enrollment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enrolled in OTC</td>
<td>0.3%</td>
<td>0.3%</td>
<td>0.3%</td>
<td>0.0%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Enrolled in A.A. program</td>
<td>4.7%</td>
<td>4.8%</td>
<td>4.8%</td>
<td>0.9%</td>
<td>5.8%</td>
</tr>
<tr>
<td>Enrolled in B.A. program</td>
<td>5.9%</td>
<td>6.1%</td>
<td>6.3%</td>
<td>0.3%</td>
<td>7.7%</td>
</tr>
<tr>
<td>Unemployed or outside Ohio workforce</td>
<td>23.2%</td>
<td>22.5%</td>
<td>18.7%</td>
<td>44.2%</td>
<td>16.5%</td>
</tr>
<tr>
<td>Employed within manufacturing since 2007</td>
<td>1.7%</td>
<td>1.6%</td>
<td>1.3%</td>
<td>5.2%</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

**SOURCE:** Features OLDA data linked to data on quarterly wages and industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance (CHRR at The Ohio State University, undated).

**NOTE:** We restricted the sample to individuals who first appeared in the Ohio workforce data between 2007 and 2013 and who were working in manufacturing in 2019 (full time or part time). We examine their postsecondary education enrollment from 2006 to 2019 and employment history from 2007 to 2019. Note that there are some individuals for whom gender data were missing, which is why we see a lower percentage coming from postsecondary enrollment in the “All” column than in each separate gender column. The top industry for all groups is ASWMRS; the second-highest industry is retail trade for the full sample, male workers, female workers, and younger workers and wholesale trade for older workers; and the third-highest industry is accommodation and food services for the full sample, male workers, female workers, and younger workers and retail trade for older workers. See Appendix A for more information on this sample.

---

\(^3\) If a student came from more than one postsecondary program, we chose the highest-level program when determining the student’s pathway.
outside Ohio’s workforce (note that the latter category includes individuals who dropped out of Ohio’s labor force, those who are unemployed, and those whom we cannot track in our data—i.e., individuals who were previously self-employed or federally employed or who were outside the state). We also include the share of individuals employed continuously in manufacturing since 2007 (and thus not coming from one of the aforementioned categories). We examine individuals coming from any enrollment in a higher educational institution (rather than just those who completed degrees) because this represents the broadest view of the education-to-workforce pipeline.

As shown in the table, nearly two-thirds of workers enter manufacturing from a job (full time or part time) in another Ohio industry. The most common industries from which they enter are ASWMRS (25 percent of switchers), retail trade (9 percent of switchers), and accommodation and food services (8 percent of switchers). These numbers highlight that movement from other industries into manufacturing is important for bolstering the pipeline of manufacturing workers. They could also indicate which backgrounds may be well suited for work in manufacturing and/or the types of industries from which manufacturing may be seen as a desirable (and potentially higher-paying) transition.

A smaller share enter manufacturing after enrolling in an Ohio postsecondary institution; less than 1 percent come from an OTC, 5 percent come from an associate degree program, and 6 percent enter from a bachelor’s degree program. Among students who enter from a postsecondary program, the most common fields of study (not shown in the table) are engineering (23 percent); business, management, and marketing (20 percent); and engineering technologies/technicians (12 percent). Given that both engineering and engineering technologies/technicians are under the manufacturing-related degree group, this means that at least 36 percent of individuals entering the manufacturing industry from education were studying in a manufacturing-related field.

Table 5.1 also presents differences by demographic subgroups. Men and women appear to have similar pathways in terms of coming more from industry than from education. We do see larger differences for older versus younger workers: A much smaller share of older workers come from postsecondary enrollment or another industry than from unemployment or outside Ohio’s workforce.

**Retention and Upskilling**

Next, we look at the retention of manufacturing workers. As discussed above, for this analysis, we use the recent entrants sample but restrict it to those individuals who were working full time in 2013. Among this sample of more-recent entrants, retention in the manufacturing industry is lower than among the broader sample of workers previously examined in Chapter 4. (This is consistent with other evidence that younger workers tend to have lower retention rates; see U.S. Bureau of Labor Statistics, 2022.) Among those working full time in manufacturing in 2013, 63 percent were still employed (full time or part time) in manufacturing in 2016 and 48 percent were still employed (full time or part time) in manufacturing in 2019. The remaining share of those who left is shown in Figure B.3 (in Appendix B).

---

4 The top industry for all groups is ASWMRS; the second-highest industry is retail trade for the full sample, male workers, female workers, and younger workers and wholesale trade for older workers; and the third-highest industry is accommodation and food services for the full sample, male workers, female workers, and younger workers and retail trade for older workers. See Appendix A for more information on this sample.

5 Additional individuals may enter the Ohio manufacturing industry from postsecondary institutions that are not covered by our data.

6 In 2016, 59 percent were employed full time (and 4 percent were employed part time); in 2019, 46 percent were employed full time (and 3 percent were employed part time).
Finally, we examine the experiences of manufacturing workers employed full time in 2013 who choose to subsequently pursue education. This is useful for understanding opportunities for upskilling. As shown in Figure 5.1, among these workers, 11 percent attended an Ohio postsecondary institution between 2013 and 2019; the majority enrolled in a two-year (6 percent) or four-year program (2 percent) rather than a shorter-term credential. However, only 28 percent of the workers attending an Ohio postsecondary institution pursued a manufacturing-related program, indicating that there is not a significant amount of upskilling in manufacturing-related fields at Ohio’s public postsecondary educational institutions. Among workers who earned a degree (not shown), 37 percent earned a degree in a manufacturing program, which indicates that success rates may be higher for those workers who pursue manufacturing programs than for those who pursue other programs. While men and women in this sample enroll in Ohio postsecondary institutions at similar rates (12.7 percent versus 13.0 percent), men are more likely than women to enroll in a manufacturing-related program (4.3 percent versus 1.1 percent). These results suggest that there may be potential to expand upskilling in manufacturing among women.

We also examine the wages of workers who subsequently pursue postsecondary education. Figure B.4 (Appendix B) shows that, while full-time manufacturing workers in 2013 who subsequently pursued postsecondary education had lower initial wages on average than those who did not pursue postsecondary education, pursuit of postsecondary education is correlated with an increase in wages six years later, which somewhat closes the wage gap between those who pursued more education and those who did not. Regression

FIGURE 5.1
Share of Full-Time Manufacturing Workers in 2013 Who Subsequently Pursued Postsecondary Education

SOURCE: Features OLDA data linked to data on quarterly wages and industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance (CHRR at The Ohio State University, undated).
NOTE: We restricted the sample to individuals who first appeared in the Ohio workforce data between 2007 and 2013 and who were full-time workers in 2013. We examine their postsecondary education from 2013 to 2019. See Appendix A for more information on this sample.

7 The 11 percent of workers attending an Ohio postsecondary institution between 2013 and 2019 includes enrollments for all degree levels, including postbaccalaureate degrees, and the limited data we have on certificate enrollments.
8 The rates for men and women are higher than the overall enrollment rates because gender information is missing for several workers, and these workers have lower enrollment rates.
9 For this analysis, we examine both full-time and part-time wages given that we examine a broader sample of full-time and part-time workers.
models that condition on workers’ 2013 wages also indicate a return of approximately $6,000 by 2019 for workers who pursued postsecondary education and a return of $9,000 for those who pursued manufacturing postsecondary education. This highlights that upskilling may be one avenue for increasing wages and retaining more workers.

We also examine the demographic characteristics of full-time manufacturing workers in 2013 who enrolled in an Ohio postsecondary institution at some point from 2013 to 2019 (Table B.12). Of manufacturing workers who pursued education during this period, 78 percent were male and 79 percent were white. These numbers align with the demographics of the manufacturing workforce. Additionally, 93 percent of workers who pursued manufacturing-related education were male, indicating that women were less likely to pursue manufacturing-related education than men even after working in manufacturing. This gap could be due to occupational differences—for example, if some of the women had clerical or office jobs rather than production roles. Black workers were also less likely to pursue manufacturing education than to pursue education in general. Table B.13 summarizes differences in the level of education pursued by gender and race/ethnicity.

Summary

The above results highlight that there are several pathways into the manufacturing workforce and that the largest share of workers enter from another industry. Thus, tapping workers in other industries could be one way to expand the pool of manufacturing workers. Retention for this sample is similar to the patterns shown in Chapter 4, reinforcing that more work can be done to reduce attrition among these recent entrants. Additionally, rates of upskilling are low, suggesting that additional upskilling could be a useful means to reduce pay gaps, particularly for lower-skilled workers.
CHAPTER 6

Potential for Expanding and Diversifying Ohio’s Manufacturing Workforce

The previous chapters point to four key areas for improving retention and diversity in the pipeline of manufacturing workers and drawing in new manufacturing workers: (1) examining the reasons for attrition from education to employment in manufacturing and crafting related policy solutions, (2) employing targeted efforts to improve the earnings and retention of female and non-white workers, (3) identifying ways to improve retention within the manufacturing industry and opportunities to combat attrition through upskilling, and (4) drawing in new workers from other industries. We discuss each of these below.

First, as evident from the analyses in Chapter 3, the majority of Ohio students with manufacturing-related credentials are not employed in Ohio manufacturing after completing their credentials. This finding is consistent with prior research (Brown et al., 2022). Attrition from education to employment is even larger among female and non-white students, as might be expected in a disproportionately male and white industry. Although our measure of attrition is limited by our imperfect measure of a student’s intention to work in the manufacturing industry (because we have only their field of study), our results suggest that there is a much larger supply of highly skilled workers with manufacturing-related expertise than is currently being utilized by the manufacturing industry.

Identifying ways to reduce attrition from manufacturing education to the manufacturing workforce will be important for growing the pipeline of highly skilled workers and expanding the diversity of the workforce. If this attrition is driven by supply-side factors, such as students not wanting to work in manufacturing, then policy interventions focused on increasing students’ awareness of or exposure to manufacturing jobs may be beneficial so that students do not perceive manufacturing as having bad hours and being unsafe. Historically, manufacturing employers and associations have sought ways to showcase manufacturing careers to students during their training, such as through apprenticeships and internships, to mitigate negative stereotypes. Prior research has shown that the apprenticeship and internship model can be effective for reducing barriers to employment in a given industry (Helper et al., 2016).

However, many students in manufacturing-related programs may already have some familiarity with manufacturing, since they have selected into related credentials; thus, other factors may also be responsible for the high attrition rates. These factors could include a broader skills mismatch or other demand-side forces. For instance, students may seek manufacturing positions but be unable to secure them because of mismatches between their skills and employer needs. In this case, employers and postsecondary institutions would need to work more closely with one another to make sure that students learn skills relevant to the positions they seek. Local labor market conditions could also be at play: When we examined geographic differences, we found lower attrition from manufacturing-related education to manufacturing employment in counties where there was a greater density of manufacturing employers. In this case, policy could be oriented toward understanding and addressing geographic frictions that workers may face. In general, wages in the manufacturing industry relative to wages in other industries do not seem to be a driving factor of the education-to-employment attrition: Manufacturing wages in Ohio tend to be high relative to those of other
industries, and students with manufacturing-related credentials who work in nonmanufacturing industries earn lower wages than their peers in the manufacturing industry. More research is needed to understand the education-to-employment pipeline for the manufacturing industry and how it compares with the pipelines for other industries, both within and outside Ohio. Interviews with students, colleges, and employers or surveys of these populations may be particularly helpful in this regard, as qualitative data could help unearth the mechanisms underlying these patterns.

Second, our analyses indicate that Ohio’s manufacturing industry struggles with employment disparities for minorities, specifically female and non-white individuals. While low representation of non-white workers could be attributable to the demographic composition of Ohio, the female share of workers in manufacturing is much lower than in the state as a whole. In addition, non-white and female students are underrepresented in manufacturing-related programs, and workers from underrepresented minority backgrounds have lower wages than their peers once they join the full-time manufacturing workforce. More research is needed to understand the role of gender and racial pay inequity on worker perceptions of and attitudes toward the manufacturing industry. From a policy perspective, employers could do more work to understand the characteristics of specific occupations within the manufacturing industry for which gender and racial pay gaps are lower (e.g., more-flexible hours, greater representation of women); having this knowledge could help inform best practices for reducing pay gaps in the industry. Furthermore, increasing representation of female and non-white students in manufacturing-related programs could help diversify the pipeline of highly skilled workers and help more workers from underrepresented minority backgrounds move into higher-paying positions.

There are also demographic disparities in retention, as women leave for jobs in nonmanufacturing industries at a higher rate than men. In our data, the women who leave have the same pay as the women who stay, so wages do not appear to be a major factor. From a policy perspective, this suggests that there may be other characteristics of manufacturing jobs that could be changed to affect retention. For example, if a lack of diverse representation is a primary reason for attrition (U.S. Census Bureau, 2023a; U.S. Department of Commerce, 2021), then employers could work with postsecondary institutions to develop a pipeline of underrepresented talent and offer specific incentives to encourage retention at key milestones of a worker’s career. More research could also be done to understand the reasons people leave and potential policies to address them.

Third, our analyses highlight that the industry could do more to improve retention. Roughly 10 percent of workers leave employment in manufacturing for employment in another industry in Ohio. Unfortunately, it is difficult to tell why they are leaving. Additional data, particularly regarding job features (e.g., hours, work conditions, culture, or promotion opportunities) are needed to better understand this. To combat low retention, postsecondary institutions and employers could work together to provide information about upskilling, which is relatively low in the industry. This may be a particularly promising option for lower-skilled or lower-wage workers: Upskilling is associated with pay increases (a good thing for these workers), and skills-based hiring is associated with higher retention (which is relatively low for this group) (Santhosh and Lewis, 2021). Upskilling may also be useful for women, who pursue subsequent postsecondary education at relatively high rates but are much less likely than men to pursue manufacturing-related training.

Fourth, our analyses indicate that, among recent entrants, manufacturing workers primarily enter the manufacturing workforce from other industries, as opposed to directly from education. This suggests that such industries as ASWMRS, accommodation and food services, and retail trade could be promising areas for expanding the pipeline of manufacturing workers. Employers could do more to advertise job opportu-
nities among these types of workers, focusing on the relative advantages of working in the manufacturing industry compared with these related industries.

These suggestions represent a starting point for understanding potential ways to expand the pool of diverse, skilled workers in Ohio’s manufacturing industry and draw in new types of workers. Continued efforts to understand the motivations and perspectives of students and employers, as well as greater collaboration between educational institutions and employers, will be necessary to meet the demands of the manufacturing industry going forward.
Additional Details on Data Sources and Methods

American Community Survey

Our analyses comparing Ohio with the rest of the United States used data from the ACS (U.S. Census Bureau, 2023a). We used the five-year ACS samples in 2005, 2009, and 2014 to examine time trends in wages, and we used the one-year 2019 ACS sample to examine the latest point-in-time estimates for demographic characteristics. We chose to use 2019 data (as opposed to data from later years) to avoid issues that occurred with data collection during the COVID-19 pandemic.

Standard earnings adjustments include multiplying top-coded wages by 1.5 and removing workers who earned below the federal hourly minimum wage (assuming 2,080 hours worked per year). All earnings are presented in 2019 dollars for comparability. We used person-level weights in all of our analyses to ensure that our figures are representative of the population. We defined manufacturing using standard U.S. Census and North American Industry Classification System codes; we specifically considered the Census codes from 1070 to 3990 to be part of the manufacturing industry (U.S. Census Bureau, 2020).

We restricted the sample to full-time, working-age individuals (individuals aged 18 to 64 working at least 40 hours per week and 40 weeks per year). There are a significantly smaller number of Black and Hispanic workers in Ohio, so these estimates do not have as much precision.

Ohio Longitudinal Data Archive

Education Data: Ohio Higher Educational Institutions and Technical Colleges

Data on students in higher educational institutions contain information about when each student first enrolled in a college or program, the duration of their enrollment, the program type, courses taken, grades, whether and when the student earned a degree, and the type of degree earned. The OTC data are similar but do not provide a reliable way to identify credentials as being from manufacturing programs, so we instead used course enrollments and completions. These data also contain information on student demographics, such as gender, age, and race/ethnicity. These data cover enrollments and degrees earned between 2006 and 2019. Because of limitations in the coverage of the certificate enrollment data, we do not focus on enrollments in certificate programs.

Employment Data: Ohio Unemployment Insurance Records

The Ohio unemployment insurance records contain quarterly information on workers’ jobs and wages. The wage records contain information for up to five jobs per worker each quarter, including information about total wages earned from each employer and the industry of the employer. We aggregated these data to the calendar year and focused on total annual earnings across all jobs reported in these records. Note that this could include overtime pay given that we received a measure of total income earned.
For each worker, we defined their primary industry in each calendar year as the industry in which they earned the most wages. Thus, our sample of manufacturing workers is based on individuals for whom manufacturing was the industry in which they earned the most income in the calendar year. Each worker was assigned only one industry.

For each worker-industry pair, we then defined whether the individual worked part time or full time in the given industry. As discussed earlier, we used a proxy for full-time status: whether workers’ annual earnings were at least the minimum wage in Ohio in the given year times 2,080 hours of work (assuming 40 hours per week and 52 weeks per year). In 2021, this implies that a full-time worker in Ohio was earning at least $18,304 per year ($8.80 per hour x 2,080 hours). Any worker-industry pair that was not considered full time based on the above definition was characterized as part time.

These data span from 2003 to 2021. All wage estimates are converted to 2021 dollars. These data are based only on employment in Ohio jobs covered by unemployment insurance. Thus, workers who were employed in other states—as well as workers whose jobs were not covered by the state’s unemployment insurance program, including those who were self-employed or employed by the federal government—are missing in the data.

Note that data on gender and age are available via supplemental driver’s license records, which do not include race/ethnicity. For our analyses that used age, we restricted the sample to workers aged 16 to 72 (representing between the first and the 99th percentile of age in the dataset). There are individuals with missing gender and age in the dataset, and we kept these individuals for analyses that did not use age or gender.

Analysis Samples
We drew on several samples for our analyses. Table A.1 presents the characteristics of each sample, the analyses it was used for, the total sample size, the education data sample size (if used for creation of the particular sample), the employment data sample size (if used for creation of the particular sample), and the match rate between the education and employment data (if the datasets were linked to create the particular sample).

Definition of Manufacturing-Related Credentials Using CIP Codes
We defined manufacturing-related programs and credentials as follows. The primary specification used in the report consists of CIP code 15 (engineering technologies and technicians), CIP code 48 (precision production), and a subset of seven CIP codes within CIP code 14 (engineering): mechanical engineering (14.19), electrical and electronics engineering (14.10), industrial engineering (14.35), materials engineering (14.18), construction engineering (14.33), manufacturing engineering (14.36), and polymer/plastics engineering (14.32). We chose this subset using the following procedure:

• First, using the U.S. Department of Labor’s O*NET keyword search (O*NET OnLine, 2023), we identified the top 20 occupations associated with the word manufacturing.
• Next, we used the O*NET database to identify the training and credentials in Ohio associated with each of the 20 occupations (as of August 2022). These data include the program name (e.g., “industrial engineering”), the school (e.g., “Ohio State University – Main Campus”), and the number of recent graduates (e.g., 122 graduates with a bachelor’s degree).
• Then, we aggregated the data to determine the programs with the highest numbers of graduates with a bachelor’s degree, an associate degree, and a certificate. From these three lists, we chose the programs within CIP code 14 that either had a high number of graduates (e.g., “mechanical engineering” for the bachelor’s degree category) or were particularly relevant to manufacturing (e.g., “manufacturing engineering” appeared in both the bachelor’s degree and certificate lists). In general, we drew more from the bachelor’s degree list than from the certificate and associate degree lists. The certificate and asso-
**TABLE A.1**

Characteristics and Match Rates of Samples Used for Analyses

<table>
<thead>
<tr>
<th>Sample Name</th>
<th>Characteristics</th>
<th>Analyses</th>
<th>Sample Size</th>
<th>Match Percentage Between Education and Employment Data</th>
</tr>
</thead>
</table>
| Educational pipeline sample | All public postsecondary students in Ohio who enrolled in or completed a manufacturing program from 2006 to 2019 | Chapter 3 analysis on enrollments and completions | • 234,399 observations at the person level for those who enrolled in manufacturing-related program  
• 67,455 observations at the person level for those who completed a manufacturing-related program | N/A |
| Educational pipeline linked to workforce data | All public postsecondary students in Ohio who completed a manufacturing program from 2006 to 2019 and have a subsequent employment outcome (from 2006 to 2021) | Chapter 3 analysis on industry of employment and wages linked to educational records | 62,333 observations at the person level for those who completed a manufacturing-related program with a subsequent employment outcome | Of the 62,333 observations, 47,068 (75.5 percent) matched to the workforce data; unmatched observations include public postsecondary students in Ohio who were unemployed or out of the Ohio workforce |
| Manufacturing workforce sample focused on wage analysis | All manufacturing workers in jobs between 2003 and 2021 and employed full time in every year who are covered by Ohio’s unemployment insurance system | Chapter 4 analysis examining manufacturing workers’ wages | 2,036,663 observations at the person level | N/A |
| Manufacturing workforce sample focused on retention analysis | All full-time manufacturing workers in 2013 in jobs covered by Ohio’s unemployment insurance system | Chapter 4 analysis examining manufacturing workers’ retention three and six years later (i.e., in 2016 and 2019) | 656,169 observations at the person level | N/A |
| Recent entrants to manufacturing workforce focused on pathways analysis | Individuals who first appeared in the Ohio workforce data between 2007 and 2013 and who were working in manufacturing in 2019 (full time or part time) | Chapter 5 analysis examining pathways into manufacturing (using postsecondary records from 2006 to 2019 and employment records from 2007 to 2019) | 128,570 observations at the person level | Of the 128,570 observations, 48,563 (37.8 percent) matched to the enrollment education data |
| Recent entrants to manufacturing workforce focused on subsequent retention and upskilling analysis | Individuals who first appeared in the Ohio workforce data between 2007 and 2013 and who were working in manufacturing full time in 2013 | Chapter 5 analysis examining retention and upskilling from 2013 to 2019 | 72,474 observations at the person level | Of the 72,474 observations, 16,903 (23.3 percent) matched to the enrollment education data |

**NOTE:** N/A = not applicable.
associate degree lists had fewer graduates within CIP code 14. Additionally, some of the program names within these two lists were more general and so would not have met our aim of corresponding closely to manufacturing-related credentials.
APPENDIX B

Additional Tables and Figures

This appendix presents Tables B.1–B.13 and Figures B.1–B.4, which are referenced in the main part of the report.

### TABLE B.1
Top U.S. States with Full-Time, Working-Age Manufacturing Workers

<table>
<thead>
<tr>
<th>State</th>
<th>Share of Workers in Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Michigan</td>
<td>27%</td>
</tr>
<tr>
<td>Indiana</td>
<td>25%</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>24%</td>
</tr>
<tr>
<td>Ohio</td>
<td>21%</td>
</tr>
<tr>
<td>Iowa</td>
<td>21%</td>
</tr>
</tbody>
</table>

**SOURCE:** Features data from the one-year 2019 ACS (U.S. Census Bureau, 2023a).

**NOTE:** We restricted the sample to full-time, working-age individuals (individuals aged 18 to 64 working at least 40 hours per week and 40 weeks per year). See Appendix A for more details about the sample. The average share of manufacturing workers across all states in 2019 was 13 percent. Note that the share of workers in manufacturing within each state would be lower if we did not restrict the sample to full-time, working-age individuals.

### TABLE B.2
Top Three Occupations, by Race/Ethnicity and Gender

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Top Occupation</th>
<th>Second-Highest Occupation</th>
<th>Third-Highest Occupation</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>Production (41%)</td>
<td>Management, business, and finance (18%)</td>
<td>Computer, engineering, and science (12%)</td>
</tr>
<tr>
<td>Black</td>
<td>Production (57%)</td>
<td>Transport and materials (14%)</td>
<td>Management, business, and finance (10%)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>Production (55%)</td>
<td>Transport and materials (14%)</td>
<td>Management, business, and finance (7%)</td>
</tr>
<tr>
<td>Female</td>
<td>Production (41%)</td>
<td>Management, business, and finance (21%)</td>
<td>Office and administrative support (14%)</td>
</tr>
<tr>
<td>Male</td>
<td>Production (43%)</td>
<td>Management, business, and finance (15%)</td>
<td>Computer, engineering, and science (13%)</td>
</tr>
</tbody>
</table>

**SOURCE:** Features data from the one-year 2019 ACS (U.S. Census Bureau, 2023a).

**NOTE:** We restricted the sample to Ohio full-time, working-age individuals (individuals aged 18 to 64 working at least 40 hours per week and 40 weeks per year). See Appendix A for more details about the sample.
### TABLE B.3
Demographic Composition of Ohio Relative to the Rest of the United States

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Rest of United States</th>
<th>Ohio</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>68%</td>
<td>86%</td>
</tr>
<tr>
<td>Black</td>
<td>9%</td>
<td>7%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>15%</td>
<td>3%</td>
</tr>
<tr>
<td>Male</td>
<td>73%</td>
<td>75%</td>
</tr>
<tr>
<td>Female</td>
<td>27%</td>
<td>25%</td>
</tr>
<tr>
<td>High school or less</td>
<td>50%</td>
<td>56%</td>
</tr>
<tr>
<td>One year of college, no degree</td>
<td>14%</td>
<td>14%</td>
</tr>
<tr>
<td>Associate degree</td>
<td>8%</td>
<td>8%</td>
</tr>
<tr>
<td>Bachelor’s degree or higher</td>
<td>28%</td>
<td>23%</td>
</tr>
<tr>
<td>Under 40 years</td>
<td>37%</td>
<td>37%</td>
</tr>
<tr>
<td>40 years or over</td>
<td>63%</td>
<td>63%</td>
</tr>
</tbody>
</table>

**SOURCE:** Features data from the five-year ACS samples in 2005, 2009, and 2014 (U.S. Census Bureau, 2023a).

**NOTE:** We restricted the sample to full-time, working-age individuals (individuals aged 18 to 64 working at least 40 hours per week and 40 weeks per year). See Appendix A for more details about the sample.

### TABLE B.4
Earnings Differences for Manufacturing Workers, by Demographic Characteristic, Controlling for Education and Occupation (2019 U.S. dollars)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Rest of United States</th>
<th>Ohio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>−13,706.2****</td>
<td>−12,749.7****</td>
</tr>
<tr>
<td></td>
<td>(94.29)</td>
<td>(309.4)</td>
</tr>
<tr>
<td>Black</td>
<td>−7,146.0****</td>
<td>−4,375.1****</td>
</tr>
<tr>
<td></td>
<td>(141.3)</td>
<td>(484.9)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>−14,858.4****</td>
<td>−4,456.8****</td>
</tr>
<tr>
<td></td>
<td>(120.6)</td>
<td>(682.7)</td>
</tr>
<tr>
<td>Asian</td>
<td>−7,916.6****</td>
<td>−5,133.6****</td>
</tr>
<tr>
<td></td>
<td>(162.8)</td>
<td>(823.5)</td>
</tr>
<tr>
<td>Other race</td>
<td>−7,294.9****</td>
<td>−6,339.1****</td>
</tr>
<tr>
<td></td>
<td>(298.7)</td>
<td>(1,155.2)</td>
</tr>
<tr>
<td>High school or lower</td>
<td>−32,984.3****</td>
<td>−30,475.1****</td>
</tr>
<tr>
<td></td>
<td>(121.0)</td>
<td>(409.0)</td>
</tr>
<tr>
<td>One year of college, no degree</td>
<td>−28,819.7****</td>
<td>−27,512.2****</td>
</tr>
<tr>
<td></td>
<td>(138.7)</td>
<td>(473.3)</td>
</tr>
<tr>
<td>Associate degree</td>
<td>−27,695.3****</td>
<td>−26,144.0****</td>
</tr>
<tr>
<td></td>
<td>(158.0)</td>
<td>(533.2)</td>
</tr>
<tr>
<td>Controls</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>1,740,637</td>
<td>109,467</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.364</td>
<td>0.366</td>
</tr>
</tbody>
</table>

**SOURCE:** Features a regression of wages on demographic characteristics using data from the five-year ACS samples in 2005, 2009, and 2014 (U.S. Census Bureau, 2023a).

**NOTE:** The coefficients reflect average wage differences relative to the omitted group. The omitted race group is white. Other race refers to all other races. The omitted education group is bachelor’s degree or higher. We restricted the sample to full-time, working-age individuals (individuals aged 18 to 64 working at least 40 hours per week and 40 weeks per year). See Appendix A for more details about the sample. Standard errors are in parentheses. *p < 0.10, **p < 0.05, ***p < 0.01, ****p < 0.001.
### TABLE B.5
Demographics of Ohio Students in Manufacturing-Related Programs Relative to Overall Ohio Student Sample from 2006 to 2019

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Enrolled in OTC Program</th>
<th>Enrolled in Associate Degree Program</th>
<th>Enrolled in Bachelor’s Degree Program</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manufacturing</td>
<td>Overall</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>Male</td>
<td>90%</td>
<td>45%</td>
<td>90%</td>
</tr>
<tr>
<td>Female</td>
<td>10%</td>
<td>55%</td>
<td>10%</td>
</tr>
<tr>
<td>White</td>
<td>89%</td>
<td>85%</td>
<td>80%</td>
</tr>
<tr>
<td>Black</td>
<td>5%</td>
<td>10%</td>
<td>15%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>3%</td>
<td>2%</td>
<td>3%</td>
</tr>
<tr>
<td>Asian</td>
<td>1%</td>
<td>1%</td>
<td>2%</td>
</tr>
</tbody>
</table>

SOURCE: Features OLDA data from Ohio higher educational records from 2006 to 2019 (CHRR at The Ohio State University, undated).

NOTE: See Appendix A for more information on this sample.

### TABLE B.6
Industry of Employment After Completing Manufacturing-Related Credential

<table>
<thead>
<tr>
<th>Industry of Employment One Year After Completion</th>
<th>OTC</th>
<th>Certificate</th>
<th>Associate Degree</th>
<th>Bachelor’s Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
<td>38%</td>
<td>27%</td>
<td>25%</td>
<td>30%</td>
</tr>
<tr>
<td>Construction</td>
<td>12%</td>
<td>14%</td>
<td>8%</td>
<td>5%</td>
</tr>
<tr>
<td>Retail trade</td>
<td>5%</td>
<td>10%</td>
<td>9%</td>
<td>1%</td>
</tr>
<tr>
<td>Professional, scientific, technical services</td>
<td>1%</td>
<td>5%</td>
<td>8%</td>
<td>14%</td>
</tr>
<tr>
<td>ASWMRS</td>
<td>8%</td>
<td>6%</td>
<td>6%</td>
<td>3%</td>
</tr>
<tr>
<td>Wholesale trade</td>
<td>4%</td>
<td>3%</td>
<td>4%</td>
<td>3%</td>
</tr>
</tbody>
</table>

SOURCE: Features OLDA data from Ohio higher educational records linked to data on quarterly wages and industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance from 2006 to 2021 (CHRR at The Ohio State University, undated).

NOTE: See Appendix A for more information on this sample. Note that the percentages within a column do not add up to 100 percent because we focused only on the top industries that students go into (as opposed to the comprehensive set of industries that they go into).
### TABLE B.7

**Industry of Employment After Completing Manufacturing-Related Credential**

<table>
<thead>
<tr>
<th>One Year After Completion</th>
<th>Men %</th>
<th>Women %</th>
<th>White %</th>
<th>Non-White %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
<td>38</td>
<td>38</td>
<td>41</td>
<td>34</td>
</tr>
<tr>
<td>Construction</td>
<td>13</td>
<td>11</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td><strong>OTC</strong></td>
<td>8</td>
<td>7</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Retail trade</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Wholesale trade</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>28</td>
<td>21</td>
<td>28</td>
<td>22</td>
</tr>
<tr>
<td>Construction</td>
<td>15</td>
<td>10</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Retail trade</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>ASWMRS</td>
<td>6</td>
<td>8</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>PST</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>26</td>
<td>20</td>
<td>26</td>
<td>20</td>
</tr>
<tr>
<td>Retail trade</td>
<td>9</td>
<td>10</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Construction</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>PST</td>
<td>8</td>
<td>7</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>ASWMRS</td>
<td>6</td>
<td>7</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>31</td>
<td>24</td>
<td>32</td>
<td>21</td>
</tr>
<tr>
<td>PST</td>
<td>14</td>
<td>12</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Construction</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Wholesale trade</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>ASWMRS</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

**Source:** Features OLDA data from Ohio higher educational records linked to data on quarterly wages and industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance from 2006 to 2021 (CHRR at The Ohio State University, undated).

**Note:** A&F = accommodation and food services; HC&SA = health care and social assistance; MGMT = management of companies and enterprises; PST = professional, scientific, and technical services. See Appendix A for more information on this sample. These percentages are not conditional on employment in Ohio.

### TABLE B.8

**Median Full-Time Wages for Students in Manufacturing-Related Programs (2021 U.S. dollars)**

<table>
<thead>
<tr>
<th>Education</th>
<th>One Year After</th>
<th>Three Years After</th>
<th>Five Years After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completed manufacturing OTC</td>
<td>$39,770</td>
<td>$44,972</td>
<td>$47,711</td>
</tr>
<tr>
<td>Completed manufacturing certificate</td>
<td>$45,606</td>
<td>$50,838</td>
<td>$54,090</td>
</tr>
<tr>
<td>Completed manufacturing associate degree program</td>
<td>$46,993</td>
<td>$54,627</td>
<td>$59,915</td>
</tr>
<tr>
<td>Completed manufacturing bachelor’s degree program</td>
<td>$65,739</td>
<td>$73,307</td>
<td>$80,282</td>
</tr>
</tbody>
</table>

**Source:** Features OLDA data from Ohio higher educational records linked to data on quarterly wages and industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance from 2006 to 2021 (CHRR at The Ohio State University, undated).

**Note:** See Appendix A for more information on this sample. Note that median wages reflect total full-time wages earned by the individual (not just the manufacturing industry wage).
### TABLE B.9
**Median Full-Time Wages for Students in Manufacturing-Related Programs One Year After Completion, by Demographic Characteristic (2021 U.S. dollars)**

<table>
<thead>
<tr>
<th>Education</th>
<th>Male</th>
<th>Female</th>
<th>White</th>
<th>Non-White</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completed manufacturing OTC</td>
<td>$40,035</td>
<td>$36,038</td>
<td>$40,599</td>
<td>$37,180</td>
</tr>
<tr>
<td>Completed manufacturing certificate program</td>
<td>$45,924</td>
<td>$42,764</td>
<td>$46,683</td>
<td>$40,806</td>
</tr>
<tr>
<td>Completed manufacturing associate degree program</td>
<td>$47,679</td>
<td>$41,101</td>
<td>$47,397</td>
<td>$43,884</td>
</tr>
<tr>
<td>Completed manufacturing bachelor's degree program</td>
<td>$65,736</td>
<td>$65,742</td>
<td>$65,998</td>
<td>$63,202</td>
</tr>
</tbody>
</table>

**SOURCE:** Features OLDA data from Ohio higher educational records linked to data on quarterly wages and industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance from 2006 to 2021 (CHRR at The Ohio State University, undated).

**NOTE:** See Appendix A for more information on this sample. Note that median wages reflect total full-time wages earned by the individual (not just the manufacturing industry wage).

### TABLE B.10
**Regression of Full-Time Wages Among Students in Manufacturing-Related Programs, by Degree Type and Industry of Employment, by Race and Gender (2021 U.S. dollars)**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Any Manufacturing-Related Credential</th>
<th>Manufacturing-Related OTC</th>
<th>Manufacturing-Related Certificate</th>
<th>Manufacturing-Related Associate Degree</th>
<th>Manufacturing-Related Bachelor's Degree</th>
<th>Employed in Manufacturing One Year Later</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>−3,696.1***</td>
<td>−2,575.7</td>
<td>−2,712.2***</td>
<td>−7,969.2***</td>
<td>−1,448.3**</td>
<td>−1,356.9*</td>
</tr>
<tr>
<td></td>
<td>(−10.28)</td>
<td>(−1.89)</td>
<td>(−3.33)</td>
<td>(−15.75)</td>
<td>(−2.85)</td>
<td>(−2.29)</td>
</tr>
<tr>
<td>N</td>
<td>43,100</td>
<td>2,884</td>
<td>9,169</td>
<td>16,904</td>
<td>16,593</td>
<td>19,228</td>
</tr>
<tr>
<td>Black</td>
<td>−7,536.6***</td>
<td>−3,810.6***</td>
<td>−6,282.2***</td>
<td>−4,839.4***</td>
<td>−7,247.4***</td>
<td>−6,332.6***</td>
</tr>
<tr>
<td></td>
<td>(−15.50)</td>
<td>(−2.87)</td>
<td>(−7.91)</td>
<td>(−6.12)</td>
<td>(−8.11)</td>
<td>(−7.07)</td>
</tr>
<tr>
<td>Asian</td>
<td>1,157.2</td>
<td>6,277.2</td>
<td>−2,147.2</td>
<td>−3,431.3*</td>
<td>−1,880.6*</td>
<td>2,939.3**</td>
</tr>
<tr>
<td></td>
<td>(1.45)</td>
<td>(1.75)</td>
<td>(−0.90)</td>
<td>(−2.28)</td>
<td>(−2.08)</td>
<td>(2.76)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>−1,736.9*</td>
<td>−4,560.3*</td>
<td>−2,399.9</td>
<td>879.7</td>
<td>−854.9</td>
<td>−763.5</td>
</tr>
<tr>
<td></td>
<td>(−2.23)</td>
<td>(−2.44)</td>
<td>(−1.71)</td>
<td>(0.65)</td>
<td>(−0.74)</td>
<td>(−0.64)</td>
</tr>
<tr>
<td>N</td>
<td>40,376</td>
<td>2,569</td>
<td>8,517</td>
<td>15,940</td>
<td>15,654</td>
<td>17,829</td>
</tr>
</tbody>
</table>

**SOURCE:** Features OLDA data from Ohio higher educational records linked to data on quarterly wages and industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance from 2006 to 2021 (CHRR at The Ohio State University, undated).

**NOTE:** This table presents a regression of wages one year after degree completion on demographic characteristics for various credential subgroups. (Note that wages reflect total full-time wages earned by the individual, not just the industry wages.) The top panel is a regression that controls for gender, and the bottom panel is a separate regression that controls for race/ethnicity. The coefficients reflect average wage differences relative to the omitted group. The regressions in the first five columns represent employment in any industry. The regression in the last column restricts the sample to the individual working in the manufacturing industry one year later and controls for educational attainment. See Appendix A for more information on the sample.
### TABLE B.11
Median Full-Time Wages Among Students in Manufacturing-Related Programs, by Degree Type and Industry of Employment (2021 U.S. dollars)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>One Year After</th>
<th>Three Years After</th>
<th>Five Years After</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manufacturing</td>
<td>Nonmanufacturing</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>Completed manufacturing OTC</td>
<td>$41,400</td>
<td>$37,474</td>
<td>$47,031</td>
</tr>
<tr>
<td>Completed manufacturing certificate program</td>
<td>$51,844</td>
<td>$41,974</td>
<td>$55,875</td>
</tr>
<tr>
<td>Completed manufacturing associate degree program</td>
<td>$52,912</td>
<td>$44,011</td>
<td>$59,421</td>
</tr>
<tr>
<td>Completed manufacturing bachelor's degree program</td>
<td>$67,567</td>
<td>$63,589</td>
<td>$74,649</td>
</tr>
</tbody>
</table>

SOURCE: Features OLDA data from Ohio higher educational records linked to data on quarterly wages and industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance from 2006 to 2021 (CHRR at The Ohio State University, undated).

NOTE: See Appendix A for more information on this sample. Note that median wages reflect total full-time wages earned by the individual (not just the industry wages).
FIGURE B.1
Retention of Students in the Manufacturing Pipeline, by Density of Manufacturing Establishments

Number of manufacturing establishments per 1,000 people in county

Retention rate of manufacturing students (percentage)

SOURCE: Features OLDA data from 2019 to 2020 linked to data on industries and counties of employment for workers employed in jobs covered by Ohio’s unemployment insurance from 2020 to 2021 (CHRR at The Ohio State University, undated).

NOTE: The sample is restricted to manufacturing employers whose establishments are all in the same county. Thus, it does not capture workers who work at multi-establishment employers with establishments in multiple counties. See Appendix A for more information on this sample. These data are linked to the number of manufacturing establishments per 1,000 people in a given county from 2021 Census County Business Patterns data (U.S. Census Bureau, 2023b). The y-axis indicates the rate of retention in the manufacturing industry for students in manufacturing-related programs; retention is defined as employment in the manufacturing industry one year after completing credentials. The x-axis indicates the number of manufacturing establishments per 1,000 people in the county.

FIGURE B.2
Median Full-Time Earnings Changes for Switchers

Panel A. Initial Earnings Change

Median 2013 wage for switchers
First-year wage change for switchers
Second-year wage change for switchers

Panel B. Longer-Term Earnings Change

Median 2013 manufacturing: Stayers
Median 2019 manufacturing: Stayers
Median 2013 manufacturing: Switchers
Median 2019 manufacturing: Switchers

SOURCE: Features OLDA data from quarterly wages and industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance (CHRR at The Ohio State University, undated).

NOTE: We restricted the sample to full-time workers in 2013 and examined their employment outcomes in 2016 and 2019. See Appendix A for more information on this sample.
FIGURE B.3
Attrition from Ohio Manufacturing Industry: Recent Cohorts

SOURCE: Features OLDA data from quarterly wages and industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance (CHRR at The Ohio State University, undated).
NOTE: We restricted the sample to individuals who first appeared in the Ohio workforce data between 2007 and 2013 and who were full-time workers in 2013. We examined their employment outcomes in 2016 and 2019. See Appendix A for more information on this sample.
FIGURE B.4
Average Earnings of Manufacturing Workers Who Pursued Postsecondary Education
(2021 U.S. dollars)

SOURCE: Features OLDA data from Ohio higher educational records linked to data on quarterly wages and industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance (CHRR at The Ohio State University, undated). NOTE: We restricted the sample to individuals who first appeared in the Ohio workforce data between 2007 and 2013 and who were full-time workers in 2013. We examined their employment outcomes in 2013 and 2019 by whether they pursued additional postsecondary education from 2013 to 2019. See Appendix A for more information on this sample.
**TABLE B.12**  
**Demographic Characteristics of Manufacturing Workers Who Pursued Postsecondary Education**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Pursued Postsecondary Education After 2012</th>
<th>Pursued Manufacturing Postsecondary Education After 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>78%</td>
<td>93%</td>
</tr>
<tr>
<td>Female</td>
<td>22%</td>
<td>7%</td>
</tr>
<tr>
<td>White</td>
<td>79%</td>
<td>83%</td>
</tr>
<tr>
<td>Black</td>
<td>10%</td>
<td>8%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>6%</td>
<td>5%</td>
</tr>
<tr>
<td>Asian</td>
<td>4%</td>
<td>4%</td>
</tr>
</tbody>
</table>

**SOURCE:** Features OLDA data from Ohio higher educational records linked to data on quarterly wages and industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance (CHRR at The Ohio State University, undated).  
**NOTE:** We restricted the sample to individuals who first appeared in the Ohio workforce data between 2007 and 2013 and who were full-time workers in 2013. We display their demographic characteristics by their postsecondary enrollment from 2013 to 2019. See Appendix A for more information on this sample.

**TABLE B.13**  
**Demographic Characteristics of Manufacturing Workers Who Pursued Various Types of Postsecondary Education Programs**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Two-Year Manufacturing Postsecondary Education Program After 2012</th>
<th>Four-Year Manufacturing Postsecondary Education Program After 2012</th>
<th>OTC Manufacturing Postsecondary Education Program After 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>95%</td>
<td>92%</td>
<td>95%</td>
</tr>
<tr>
<td>Female</td>
<td>5%</td>
<td>8%</td>
<td>*</td>
</tr>
<tr>
<td>White</td>
<td>83%</td>
<td>88%</td>
<td>84%</td>
</tr>
<tr>
<td>Black</td>
<td>8%</td>
<td>6%</td>
<td>*</td>
</tr>
<tr>
<td>Hispanic</td>
<td>5%</td>
<td>3%</td>
<td>5%</td>
</tr>
<tr>
<td>Asian</td>
<td>2%</td>
<td>3%</td>
<td>*</td>
</tr>
</tbody>
</table>

**SOURCE:** Features OLDA data from Ohio higher educational records linked to data on quarterly wages and industries of employment for workers employed in jobs covered by Ohio’s unemployment insurance (CHRR at The Ohio State University, undated).  
**NOTE:** We restricted the sample to individuals who first appeared in the Ohio workforce data between 2007 and 2013 and who were full-time workers in 2013. We display their demographic characteristics by their postsecondary enrollment from 2013 to 2019. See Appendix A for more information on this sample.  
* Starred cells indicate those for which the sample was less than ten, so the value cannot be reported per our data use agreement.
## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS</td>
<td>American Community Survey</td>
</tr>
<tr>
<td>ASWMRS</td>
<td>administrative and support and waste management and remediation services</td>
</tr>
<tr>
<td>CIP</td>
<td>Classification of Instructional Programs</td>
</tr>
<tr>
<td>COVID-19</td>
<td>coronavirus disease 2019</td>
</tr>
<tr>
<td>OLDA</td>
<td>Ohio Longitudinal Data Archive</td>
</tr>
<tr>
<td>OTC</td>
<td>Ohio Technical Center</td>
</tr>
</tbody>
</table>
References


Bohn, Sarah, Jacob Jackson, and Shannon McConville, Career Pathways and Economic Mobility at California's Community Colleges, Public Policy Institute of California, 2019.


CHRR at The Ohio State University, Ohio Longitudinal Data Archive, data repository, undated. As of July 31, 2023: https://chrr.osu.edu/ohio-longitudinal-data-archive

Daugherty, Lindsay, Peter Riley Bahr, Peter Nguyen, Jennifer May-Trifiletti, Rooney Columbus, and Jonah Kushner, Stackable Credential Pipelines and Equity for Low-Income Individuals: Evidence from Colorado and Ohio, RAND Corporation, RR-A2484-1, 2023. As of July 5, 2023: https://www.rand.org/pubs/research_reports/RRA2484-1.html


IBM, “How Industry 4.0 Technologies Are Changing Manufacturing,” webpage, undated. As of May 23, 2023: https://www.ibm.com/topics/industry-4-0


National Student Clearinghouse Research Center, Overview: Fall 2021 Enrollment Estimates, Fall 2021.


Ohio Administrative Code, Title 5703, Department of Taxation; Chapter 5703-9, Sales and Use Tax; Rule 5703-9-21, Sales and Use Tax; Manufacturing, 2019.


Ohio Manufacturers’ Association, “OMA’s $23.5M ‘Good Jobs’ Grant to Serve More Than 1,000 Manufacturers,” August 3, 2022b.


Suneson, Grant, “America’s Dying Industries: These Businesses Lost the Most Workers in Past Decade,” USA Today, December 18, 2018.


U.S. Census Bureau, “American Community Survey (ACS),” webpage, last updated 2023a. As of May 25, 2023: https://www.census.gov/programs-surveys/acs


Valdes-Dapena, Peter, “Honda and LG Are Spending $3.5 Billion to Build a Battery Factory in Ohio,” CNN Business, October 11, 2022.
