A Profile of Advanced Manufacturing in the Commonwealth:

Key Industry and Occupational Trends

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Henry Renski, PhD
Principal Investigator
Ryan Wallace
Graduate Research Assistant

Center for Economic Development
University of Massachusetts Amherst

UNIVERSITY OF MASSACHUSETTS
AMHERST

109 Hills North
111 Thatcher Road
Amherst, MA 01003-9361

Center for Economic Development
Dept. of Landscape Architecture
& Regional Planning

voice: 413.545.2255
fax: 413.545.1772

Executive Summary

This report provides a detailed examination of Advanced Manufacturing in the Commonwealth of Massachusetts. Its purpose is to provide actionable information to help guide policy and program decisions directed to securing a strong future for the state's Manufacturing sector. This report is the first in an eight-part series. It focuses on trends and conditions in Advanced Manufacturing for the Commonwealth as a whole. Later reports focus on conditions and trends in seven sub-regions within the Commonwealth. In the course of this series we examine recent employment and earnings trends; analyze key occupations in Advanced Manufacturing, looking for common labor needs across subsectors and comparing wage rates to similar workers in other industries; identify the most common and critical skills needed by employers; and offer a detailed demographic profile of the Advanced Manufacturing to highlight areas of critical concern for the future health of the industry.

Despite decades of job loses and business closures, Advanced Manufacturing remains a critical component of the Commonwealth's economy. Over 200,000 people work in the Advanced Manufacturing sector, roughly 6% of the state's entire employment base. As an export-driven sector, manufacturing brings new money into Massachusetts and helps to support jobs in local-serving sectors such as retail and personal services. It is among the highest paying major industry sectors in the state, with the average worker earning roughly $20,000 more than the state average. This is especially noteworthy considering manufacturing is one of the few remaining paths to a good-paying job for those with modest levels of formal education.

There are also signs that the Advanced Manufacturing sector may be on the cusp of a rebound. The sector lost nearly a third of its job base since 2001 and over a quarter of its establishments. These losses were heavily concentrated in the dominant Computers and Electronics Products subsector, although no subsector went unscathed. But as the economy recovers from the Great Recession, employment losses in Advanced Manufacturing have subsided. Some subsectors, such as Food Processing, Fabricated Metals, and Medical Equipment are even posting small net job gains. Yet, the pace of recovery in the State's Advanced Manufacturing sector still remains below the nation. Employers cite a dearth of workers with the technical and basic skills demanded by today's global marketplace as a major factor curtailing their ability to expand. And with more than 20% of today's workforce reaching retirement age in the next ten years, the labor shortage issue is likely to get worse in the absence of concerned efforts and cooperation by policy makers, educators, and industry leaders. However, we also find considerable overlap in the skills required by workers across the Advanced Manufacturing subsectors, suggesting ample opportunities for developing targeted training programs that still serve the needs of a wide spectrum of employers.

Table of Contents

Introduction

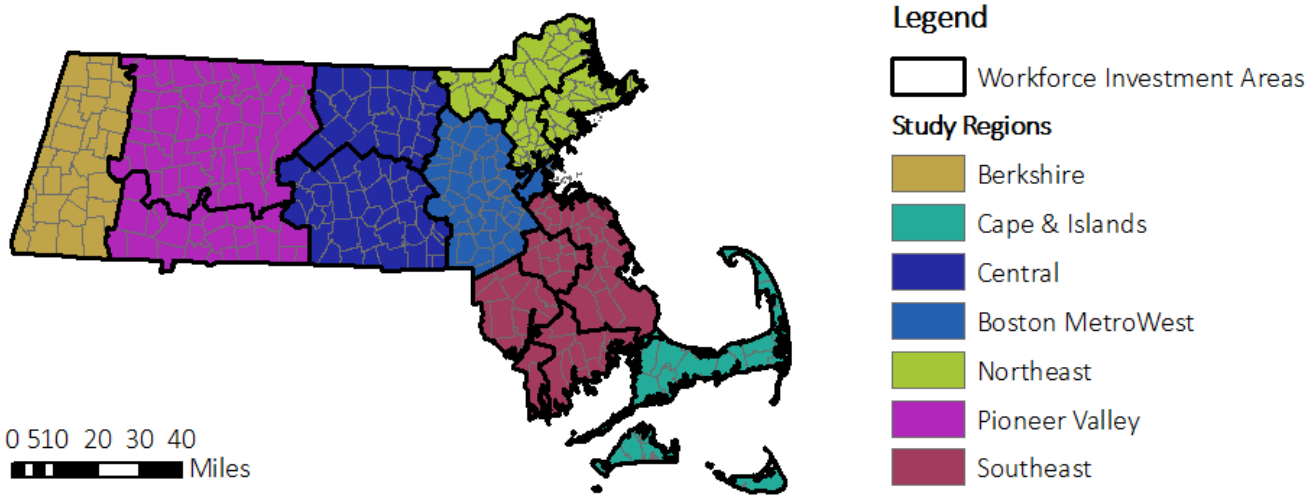
Study Purpose and Scope

This report provides a detailed examination of the industrial ecology and occupational composition of Advanced Manufacturing in the Commonwealth of Massachusetts. Its purpose is to provide up-to-date and actionable information to help guide policy and program decisions directed to securing a strong future for the state's Manufacturing sector. Our primary audience is the policy makers, workforce and education professionals, economic development officials, business leaders, and workers responsible for setting the course for manufacturing in the years ahead.

This is the first report in an eight-part series. This report provides an assessment of statewide and national trends and conditions in Advanced Manufacturing. While its focus is on the Commonwealth as a whole, this study also provides comparisons across all of the seven designated regional labor markets (Figure 1). Later reports in the series will focus on conditions and trends in specific regions. While there have been numerous studies on the Massachusetts economy in recent years, none focuses exclusively on the Advanced Manufacturing sector at a regional scale. For example, the recent "Staying Power II" report from the Dukakis Center at Northeastern University provides a comprehensive evaluation of the health of the state's manufacturing sector, but does not focus on Advanced Manufacturing or regional conditions.[1] An-

Figure 1

The Seven Study Regions (Workforce Investment Area based definitions)



[1] The Staying Power II report is available online at http://www.northeastern.edu/dukakiscenter/wp-content/uploads/2013/10/Staying-Power-II.pdf

other important precedent study by the Federal Reserve Bank of Boston examines regional labor market conditions and workforce demographics, but provides only limited consideration of the labor force within specific industries.[2] The UMASS Donahue Institute also recently conducted a comprehensive analysis of the Advanced Manufacturing sector on behalf of the Pittsfield Economic Revitalization Corporation, but it was limited to Berkshire County in Western Massachusetts.[3]

Workforce and economic developers have been asking for detailed data at the regional scale to help them design and effectively implement targeted initiative. This report opens with a review of recent industrial trends: employment, wages and salaries, and the regional impact of the recent recession and recovery. Whenever possible we benchmark our metrics against state and national averages to help establish the context and meaning underlying these trends. Despite decades of decline and outsourcing, its appears that the Advanced Manufacturing sector may be on the cusp of a rebound, and policy officials and industry leaders need to remain informed if they wish for manufacturing to remain strong in the years ahead.

Next, we move on to a detailed analysis of key occupations among the Advanced Manufacturing workforce. We identify the most prominent and specialized occupation that comprise the "core" of production in modern economy and examine their comparative wage levels and growth rates, employment shifts over the past decade, and how each compare to national and state averages. We also identify crossover occupations than are prevalent in multiple industries within Advanced Manufacturing, which provide likely targets for training programs that the offer greatest benefit to the most employers.

Following the occupational profile, we shift our attention to the specific types of skills used and required for success in today's Advanced Manufacturing workforce. Skills transcend both occupations and industries, and thus regrouping occupations in terms of complimentary and similar skills provides another venue for identifying possible targets for training and other development programs.

This report closes with a detailed profile of the people that work in Advanced Manufacturing. We pay particular attention to areas of critical concern for the future health of the industry, such as the aging of the workforce, the gender gap, commuting patterns, educational attainment, and the prevalence of foreign born workers.

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[2] The report and interactive data viewer for the Federal Reserve Bank of Boston labor market profiles can be viewed at http://www.bostonfed.org/economic/neppc/labor-market-trends-in-massachusetts-regions/

[3] The UMASS Donahue Institute study of the Berkshire's Advanced Manufacturing sector is available at http://www.donahue.umassp.edu/docs/Berkshire_Advanced_Manufacturing_Study/

What is Advanced Manufacturing?

There is no formal definition of Advanced Manufacturing, and thus the term is often used in different ways. The term "Advanced Manufacturing" evokes images of sophisticated technologies, flexibly integrated production processes, and applied science that come together to create highly value-added products. The President's Council of Advisors on Science and Technology uses such a process oriented definition defining Advanced Manufacturing as:

> ...a family of activities that (a) depend on the use and coordination of information, automation, computation, software, sensing, and networking, and/or (b) make use of cutting edge materials and emerging capabilities enabled by the physical and biological sciences, for example nanotechnology, chemistry, and biology. This involves both new ways to manufacture existing products, and especially the manufacture of new products emerging from new advanced technologies.[4]

This definition distinguishes contemporary forms of manufacturing based on integrated scientific principles, design, technology and non-routine production regimes from the massive assembly lines of the past. Advanced Manufacturing might also be defined by the technologically sophisticated and highly-value added products it creates. By this standard, semi-conductors and computer components might be included under the banner of Advanced Manufacturing, even if the processes used to make such devices is rather routine and difficult to adjust in the face of changing consumer tastes. A more practical consideration in choosing a definition is selecting and grouping industries that not only meet the 'advanced' criterion, but also include a sufficient number of employers to avoid the 'suppression' of confidential employer information that often plagues public data sources.

We follow a purposely broad definition for Advanced Manufacturing—choosing to err on the side of including less 'advanced' sectors than excluding potentially relevant targets. We followed a bottom-up approach of first identifying technologically-sophisticated and relatively homogenous sets of industries and grouping these into distinct "subsectors." Our Advanced Manufacturing sector is simply the collective sum of the individual subsectors. We began the process by reviewing recent reports and studies and compiling a long list of candidate industries that involve advanced processes or products. Next we conducted a preliminary examination of detailed industry data (at the three and four-digit NAICS code level) at multiple geographic scales. We then examined a range of measures indicative of economic importance, similarities in production processes, and growth potential—cross-industry trade patterns, the scale and relative concen-

[4] The President's Council of Advisors report is available at http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-advanced-manufacturing-june2011.pdf

tration of employment, wage growth, and whether the subsector had a significant presence across the study regions. The list was then vetted among the leadership of the Advanced Manufacturing Collaborative and the Regional Academies, at which point a few industries were added and several removed.

This process resulted in six targeted subsectors: Food Production and Processing; Paper and Printing; Chemicals and Plastics (including Pharmaceuticals); Fabricated Metal Products & Machinery (i.e. precision machining), Computer and Electronic Products, and Medical Equipment and Supplies. Table 1 provides a more detailed list of the specific industries included in each subsector.

Table 1

Advanced Manufacturing Subsector Definitions

Chemical & Plastics (incl. Pharmaceuticals)

NAICS	Description
3251	Basic chemical
3252	Resin, synthetic rubber, and artificial synthetic fibers
3253	Pesticide, fertilizer, and other agricultural chemical
3254	Pharmaceutical and medicine
3255	Paint, coating, and adhesive
3256	Soap, cleaning compound, and toilet preparation
3259	Other chemical product and preparation
3261	Plastics product

Fabricated Metal Products & Machinery

NAICS	Description
3321	Forging and stamping
3322	Cutlery and handtool
3323	Architectural and structural metals
3324	Boiler, tank, and shipping container
3325	Hardware
3326	Spring and wire product
3327	Machine shops; turned product; and screw, nut, and bolt
3328	Coating, engraving, heat treating, and allied activities
3329	Other fabricated metal product
3331	Agriculture, construction, and mining machinery
3332	Industrial machinery
3333	Commercial and service industry machinery
3334	Ventilation, heating, air-conditioning, and commercial ref
3335	Metalworking machinery
3336	Engine, turbine, and power transmission equipment
3339	Other general purpose machinery

Computer and Electronic Products

NAICS	Description
3341	Computer and peripheral equipment
3342	Communications equipment
3343	Audio and video equipment
3344	Semiconductor and other electronic component
3345	Navigational, measuring, electromedical, and control instruments
3346	Manufacturing and reproducing magnetic and optical media
3351	Electric lighting equipment

Food Processing and Production

NAICS	Description
3112	Grain and oilseed milling
3113	Sugar and confectionery product
3114	Fruit and vegetable preserving and specialty foods
3115	Dairy product
3116	Animal slaughtering and processing
3117	Seafood product preparation and packaging
3118	Bakeries and tortilla
3119	Other food

Paper and Printing

NAICS	Description
3221	Pulp, paper, and paperboard mills
3222	Converted paper product
3231	Printing and related support activities

Medical Equipment and Supplies

NAICS	Description
3391	Medical equipment and supplies

Industry Trends in Massachusetts

As of 2012, there were just over 5,300 establishments and 200,000 workers in Advanced Manufacturing, representing roughly 6 percent of the total employment base of the Commonwealth and nearly 80 percent of its Manufacturing employment base (Table 2). The state's share of employment in Advanced Manufacturing nearly matches the national average, as revealed by a location quotient close to one. However, the distribution of Advanced Manufacturing employment within the state is highly uneven. (Figure 2). While the Northeast, Boston MetroWest and Southeast regions contain the most employment, Advanced Manufacturing represents a disproportionately high share of the employment base in Central, Northeast, and Pioneer Valley regions — each exceeding the national employment share of 6.1%.

Advanced Manufacturing has suffered considerable job losses and plant closures over the past twelve years. Since 2001 the sector has lost roughly a quarter of its establishment base and a third of its employment base—the largest decline of any of the 12 major sectors. The burden of these job losses has impacted some regions more than others (Figure 3). Job losses essentially follow the overall regional employment patterns in Advanced Manufacturing. In absolute numbers, the Northeast region had the most losses, followed by Boston MetroWest and the Southeast region. Yet the Berkshires and Central region were hit the hardest relative to their size, with job losses over the past twelve years equivalent to 5.8 and 4.3 percent of

Table 2
Employment, Establishment, and Earnings Summary by Major Industry Sectors, 2012

	Establishments			Employment			Real Wage and Salary Earnings*	
Sector	Number	Change from 2001	Average Size	Number	Change from 2001	Location Quotient	per Worker	Change from 2001
Advanced Manufacturing	5,334	-1,701	37.6	200,743	-100,578	1.01	$84,584	$8,693
Other Manufacturing	1,819	-754	28.2	51,274	-36,637	0.53	$67,687	$9,576
Natural Resources and Mining	1,051	8	7.7	8,056	224	0.16	$53,820	$8,368
Construction	18,990	1,042	6.7	126,579	-24,691	0.89	$65,623	-$470
Trade, Transportation and Utilities	42,406	-1,408	13.7	578,982	-49,389	0.89	$45,699	-$2,854
Information	4,407	-562	21.0	92,386	-25,365	1.33	$95,005	$9,607
Financial Activities	16,077	626	12.9	207,425	-21,463	1.11	$116,073	$12,099
Professional and Business Services	42,278	4,574	11.8	498,182	8,216	1.12	$88,497	$12,045
Education and Health Services	20,919	2,595	41.7	872,495	148,521	1.15	$55,350	$6,268
Leisure and Hospitality	19,628	2,590	16.9	331,470	46,770	0.95	$23,036	-$798
Other Services	44,718	20,050	3.2	141,719	28,111	1.25	$29,220	-$3,555
Public Administration	3,413	433	39.4	134,321	-6,190	0.75	$65,558	$6,477
Total, all industries	221,040	27,493	14.7	3,243,632	-32,471	1.00	$62,111	$2,743

*Measured in 2013 dollars

Source: Massachusetts Department of Labor, Quarterly Employment and Wages (ES-202), Author's Calculations

their respective regional employment base in 2001. Later we will show that the regional impact of these losses are, in part, a consequence of varied regional specializations in the specific Advanced Manufacturing subsectors.

Despite these dramatic declines, Advanced Manufacturing remains a vital part of the Commonwealth economy. First, the job losses of the past twelve years were heavily concentrated in the early years of the millennia and the Great Recession of 2008. The sector has been relatively stable in the years between and since. For example, between 2001 and 2002 Advanced Manufacturing posted its highest employment loss of the study period—losing just over 35,000 workers in a single year (Figure 4). Another 15,000 Advanced Manufacturing jobs were lost from 2002 to 2003. Approximately half of these were in the Computer and Electronic Products subsector, with another 23% in

Figure 2
Regional Distribution of Advanced Manufacturing Employment

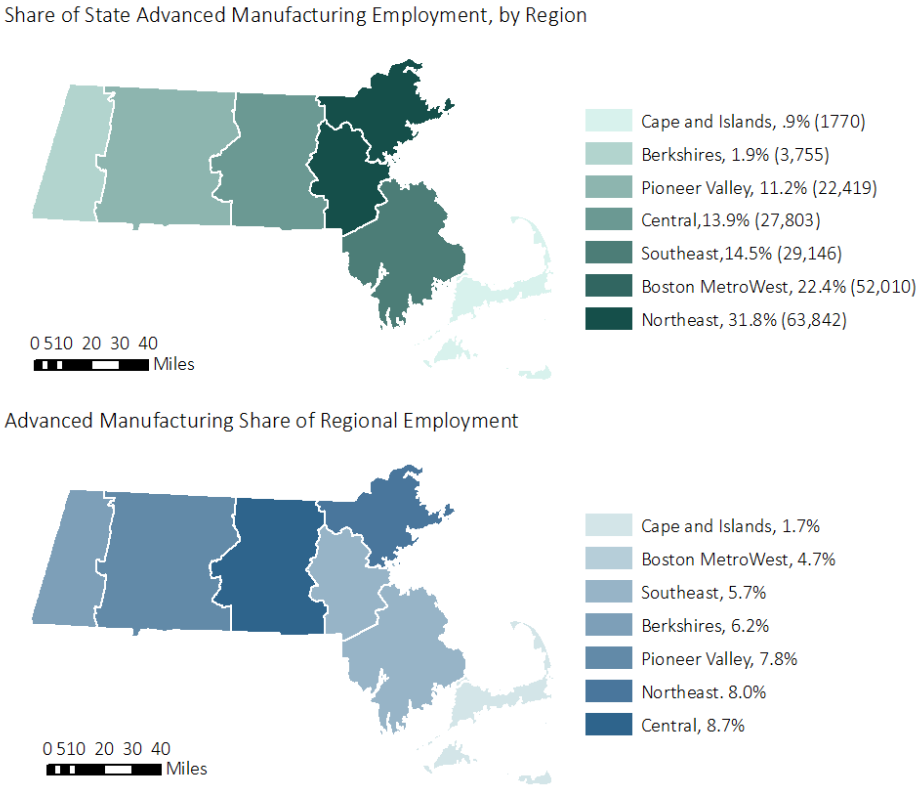
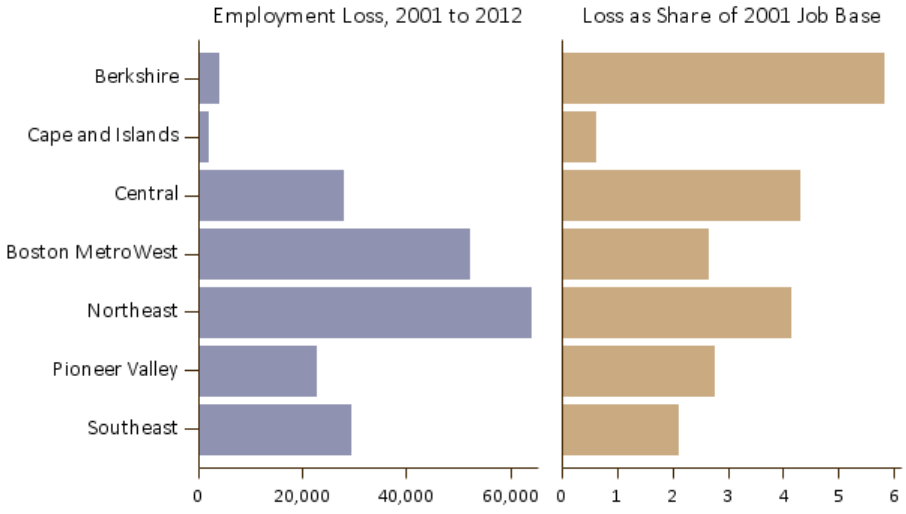


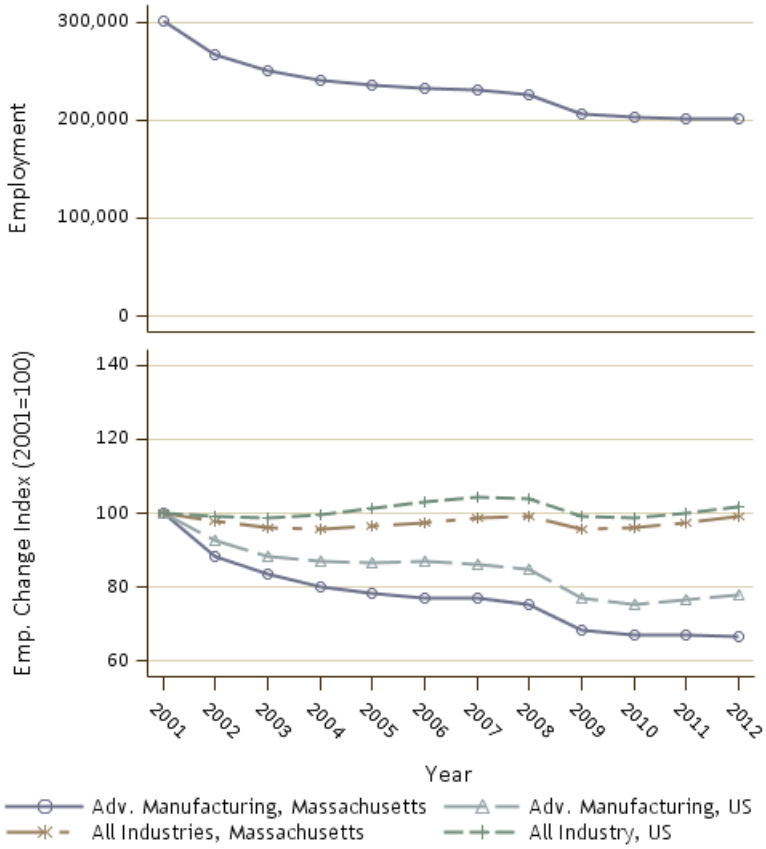
Figure 3
Regional Distribution of Job Losses in Advanced Manufacturing



Source: Massachusetts Department of Labor, Quarterly Employment and Wages (ES-202), Author's calculations

Fabricated Metals and Machinery. These losses eventually tapered off by mid-decade, but the rebound was short-lived. The Great Recession brought with it a drop of nearly 20,000 additional employees between 2008 and 2009. Since then the industry has held steady at just over 200,000 jobs. As shown in the lower portion of Figure 4, employment trends in the Massachusetts' Advanced Manufacturing sector largely mirror national trends—although the recession of the early 2000's cut Massachusetts more deeply and a had more prolonged impact. Massachusetts also did not experience the slight employment gains of the national Advanced Manufacturing sector or overall statewide economy in the post-2010 recovery.

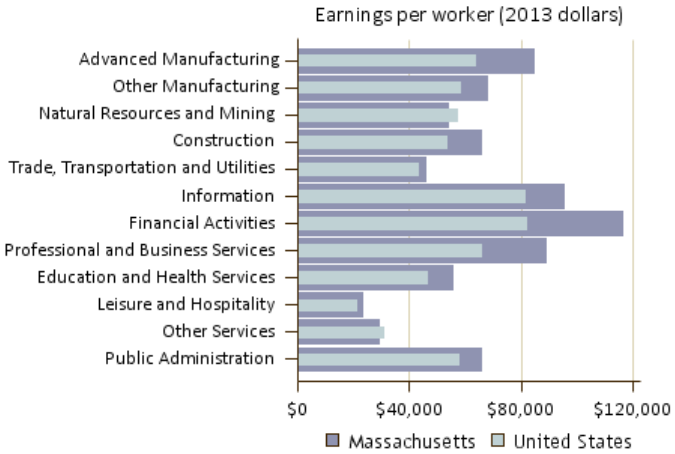
Figure 4
Annual employment change in Advanced Manufacturing, 2001 to 2012



Source: Massachusetts Department of Labor, Quarterly Employment and Wages (ES-202), Author's calculations

Advanced Manufacturing also pays considerably higher wages than most other major sectors within the state and are notably higher than the national average (Figure 5). On average, a worker in the Massachusetts Advanced Manufacturing sector earned roughly $85,000 in 2012, comparing favorably to both the state average of $62,000 and the national sector average of $63,000. Wage growth in Massachusetts' Advanced Manufacturing sector has also surpassed the nation for most of the past decade (Figure 6). The primary exception is during the Great Recession of 2008-09 where earnings growth in

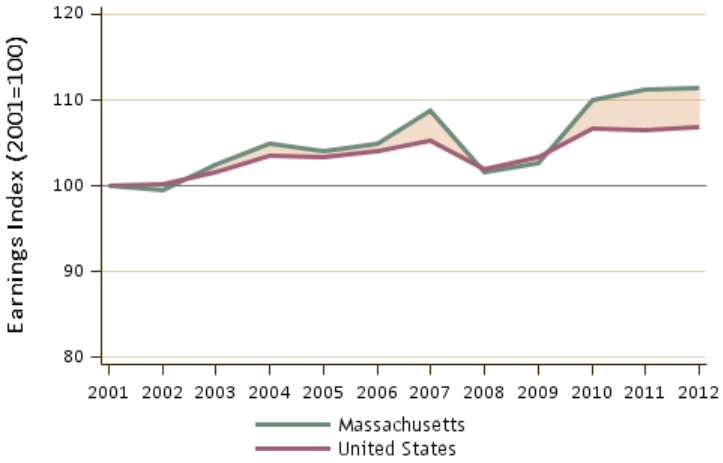
Figure 5
Average Earnings per Worker (2012), Massachusetts compared to the Nation



Source: Massachusetts Department of Labor, Quarterly Employment and Wages (ES-202), Author's calculations

the Commonwealth temporarily declined but was quick to rebound.

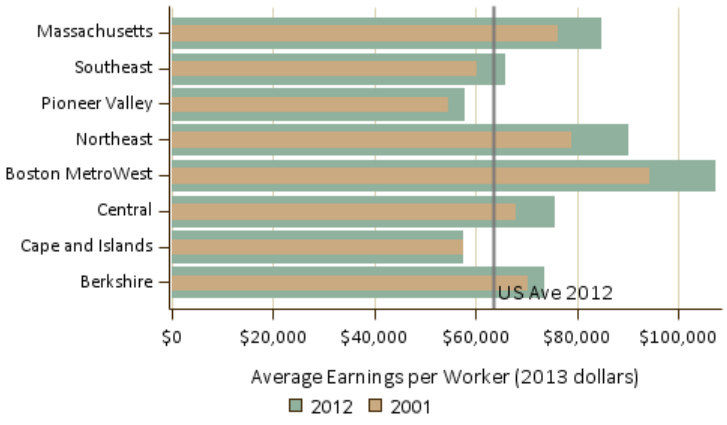
Figure 6
Trends in Real Earnings per Worker in Advanced Manufacturing, Massachusetts vs. the U.S., 2001 to 2012



Source: Massachusetts Department of Labor, Quarterly Employment and Wages (ES-202), Author's calculations

There are some substantial differences in earnings levels across regions (Figure 7). These differences are partly due to the Boston urban wage premium and partly the consequence of different regional specializations within the Advanced Manufacturing sector. Average earnings in 2012 range from roughly $57,000 per worker in the Cape and Islands to just over $109,000 in the Boston MetroWest region. Most regions fall below the state sector average of $85,000, which is pulled upward by the two largest employing regions: Boston MetroWest and Northeast. Only the Cape and Islands and Pioneer Valley fell below the national sector average of $63,000 in 2012. These two regions also experienced little real wage growth since 2001.

Figure 7
Advanced Manufacturing, Regional Earnings per Worker

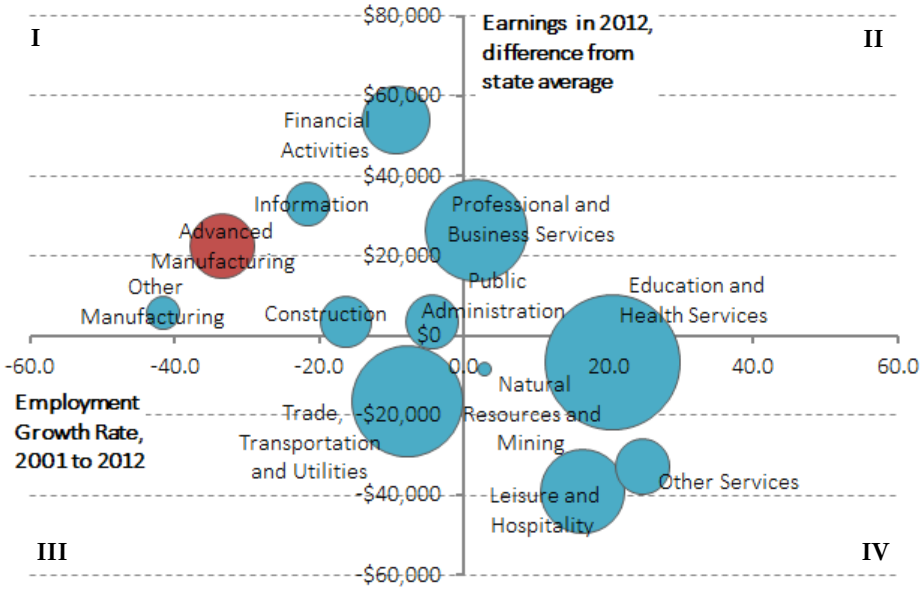


Source: Massachusetts Department of Labor, Quarterly Employment and Wages (ES-202), Author's calculations

In sum, its is clear that Advanced Manufacturing remains a staple of the Massachusetts economic base despite having experienced major job losses. As an export-driven industry, it plays a vital role in attracting new revenue into the Commonwealth—revenue that helps sustain consumer-oriented industries such as retail, personal service, and health care. The sector is also highly productive and innovative. Many companies within Advanced Manufacturing belong to expansive regional value-chains (a.k.a. clusters) in domains such as aerospace, defense, and information technology—where a critical mass of employers and skilled workers generate a competitive advantage, making the whole greater than the sum of the parts. Furthermore, Advanced Manufacturing remains one the few paths to a middle class livelihood—especially for those with modest levels of formal education. Figure 8 helps put the relative per-

formance and importance of the Advanced Manufacturing sector into perspective. The vertical axis measures the average earnings per worker for each major industry sector, relative to the state (all industry) average. The horizontal axis shows the rate of employment growth between 2001 and 2012. The size of each bubble is scaled according to its 2012 employment. Advanced manufacturing falls in quadrant I—a declining sector that pays above average wages. Only three sectors pay more than Advanced Manufacturing, two of which (Information and Financial Activities) also suffered employment losses. In fact, most of the Commonwealth's major sectors have declined since 2001. And, with the exception of Professional and Business Services, those sectors adding jobs tend to pay far less than those shedding jobs. For example, average earnings among sectors that lost jobs since 2001 was $68,000 compared to the $55,000 average among those adding net jobs.

Figure 8
Major Industry Sectors, by Average Earnings, Size, and Growth



Source: Massachusetts Department of Labor, Quarterly Employment and Wages (ES-202), Author's Calculations

Statewide Analysis of Subsectors

This section examines the recent performance of the six subsectors within the Advanced Manufacturing sector. Table 3 provides a summary of key establishment, employment and earnings statistics for the Commonwealth as a whole. We will discuss each sector briefly.

Table 3
Employment, Establishment, and Earnings Summary by Advanced Manufacturing Subsectors, 2012

	Establishments			Employment			Real Wage and Salary Earnings*	
Sub-sector	Number	Change from 2001	Average Size	Number	Change from 2001	Location Quotient	per worker	Change from 2001
Chemicals and Plastics	556	-187	49.8	27,708	-8,005	0.865	$84,903	$9,519
Computers and Electronics Products	951	-280	70.1	66,662	-50,809	1.849	$114,801	$21,460
Fabricated Metals & Machinery	1,975	-569	25.3	50,019	-22,871	0.810	$73,825	$6,033
Food Processing and Production	722	-165	33.3	24,016	1,014	0.596	$45,170	$2,019
Medical Equipment and Supplies	287	-52	41.2	11,825	-3,113	1.561	$80,104	$1,352
Paper and printing	843	-448	24.3	20,513	-16,794	0.989	$60,923	$4,626
Advanced Manufacturing (total)	5,334	-1,701	37.6	200,743	-100,578	1.011	$84,584	$8,693

*Measured in 2013 Dollars

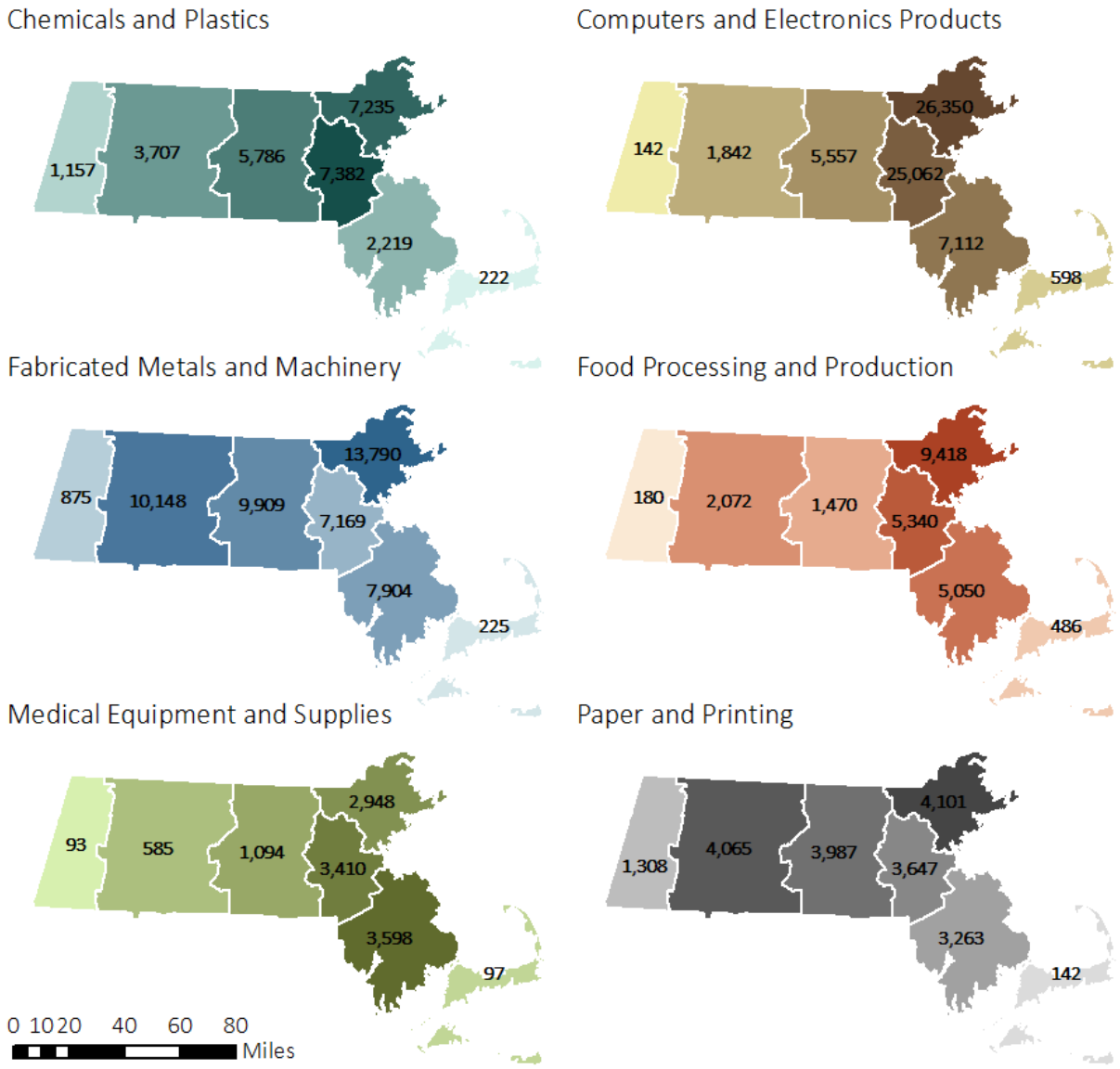
Source: Massachusetts Department of Labor, Quarterly Employment and Wages (ES-202), Author's Calculations

Chemicals and Plastics

With nearly 30,000 employees in 2012, Chemicals and Plastics is the third largest Advanced Manufacturing subsector in Massachusetts (Table 3). At fifty workers per establishment, Chemicals and Plastics has the second largest average establishment size of the six subsectors, following only Computers and Electronics. Just over half of all the Chemicals and Plastics jobs in the Commonwealth are located in the Boston MetroWest and Northeast regions (Figure 9). However, this subsector is most heavily concentrated in the Berkshires, Central, and, to a lesser extent, the Pioneer Valley regions relative to their total employment base (Figure 10).

Employment in the Chemicals and Plastics subsector has declined by nearly 8,000 workers since 2001. The overall pattern has been one of steady, but modest, decline from each year to the next—closely matching national employment trends for this subsector (Figure 11). Companies in the Boston MetroWest and Northeast regions pay the highest earnings and have also posted modest real wage growth over the past twelve years (Figure 12). The Berkshires, where the Chemicals and Plastics sector is most heavily concentrated, also pays wages at a level higher than the national average, although per worker earnings in this region have decline slightly from 2001.

Figure 9
Regional Distribution of Employment in 2012 by Advanced Manufacturing Subsector

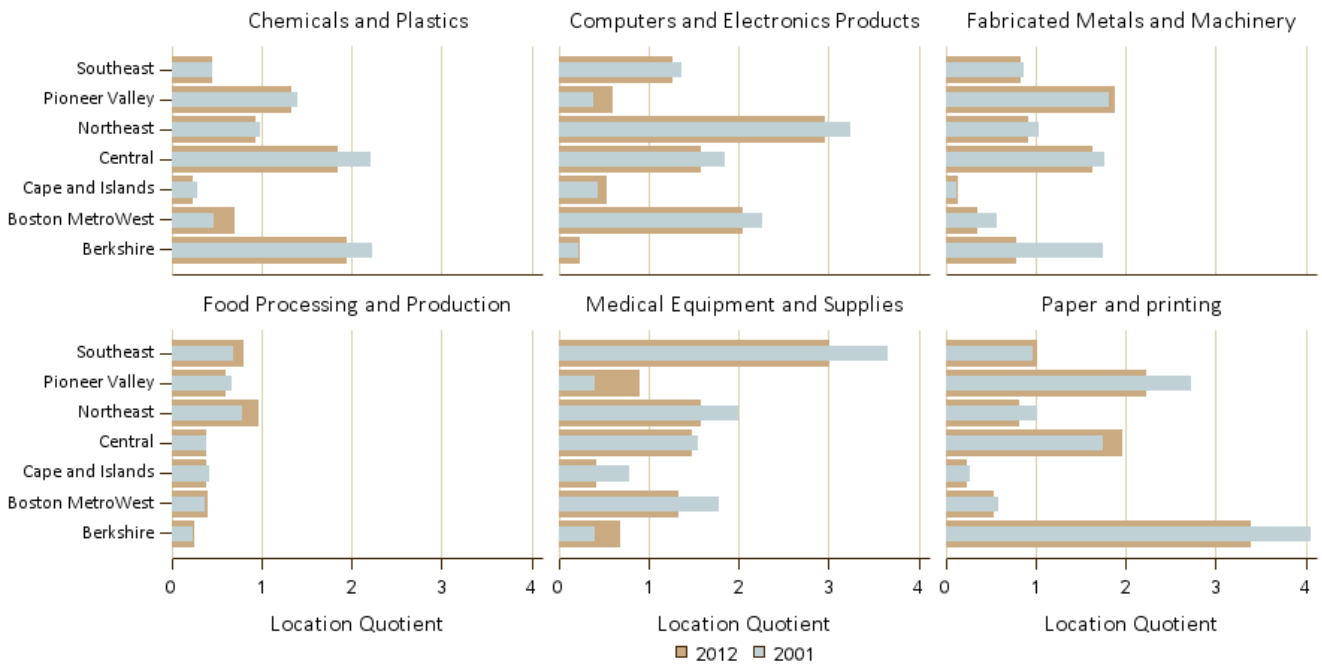


Source: Massachusetts Department of Labor, Quarterly Employment and Wages (ES-202), Author's Calculations

Computers and Electronics

Computers and electronics is the largest of the six subsectors, with over 66,000 workers in 2012—a third of the state's Advanced Manufacturing employment base (Table 3). At roughly 70 workers per establishment, employers in the Computer and Electronics sector are typically larger than those in other subsectors. It is also the most heavily specialized subsector in the Commonwealth, with nearly 80 percent of its em-

Figure 10
Relative Concentration of Employment by Advanced Manufacturing Subsector and Region



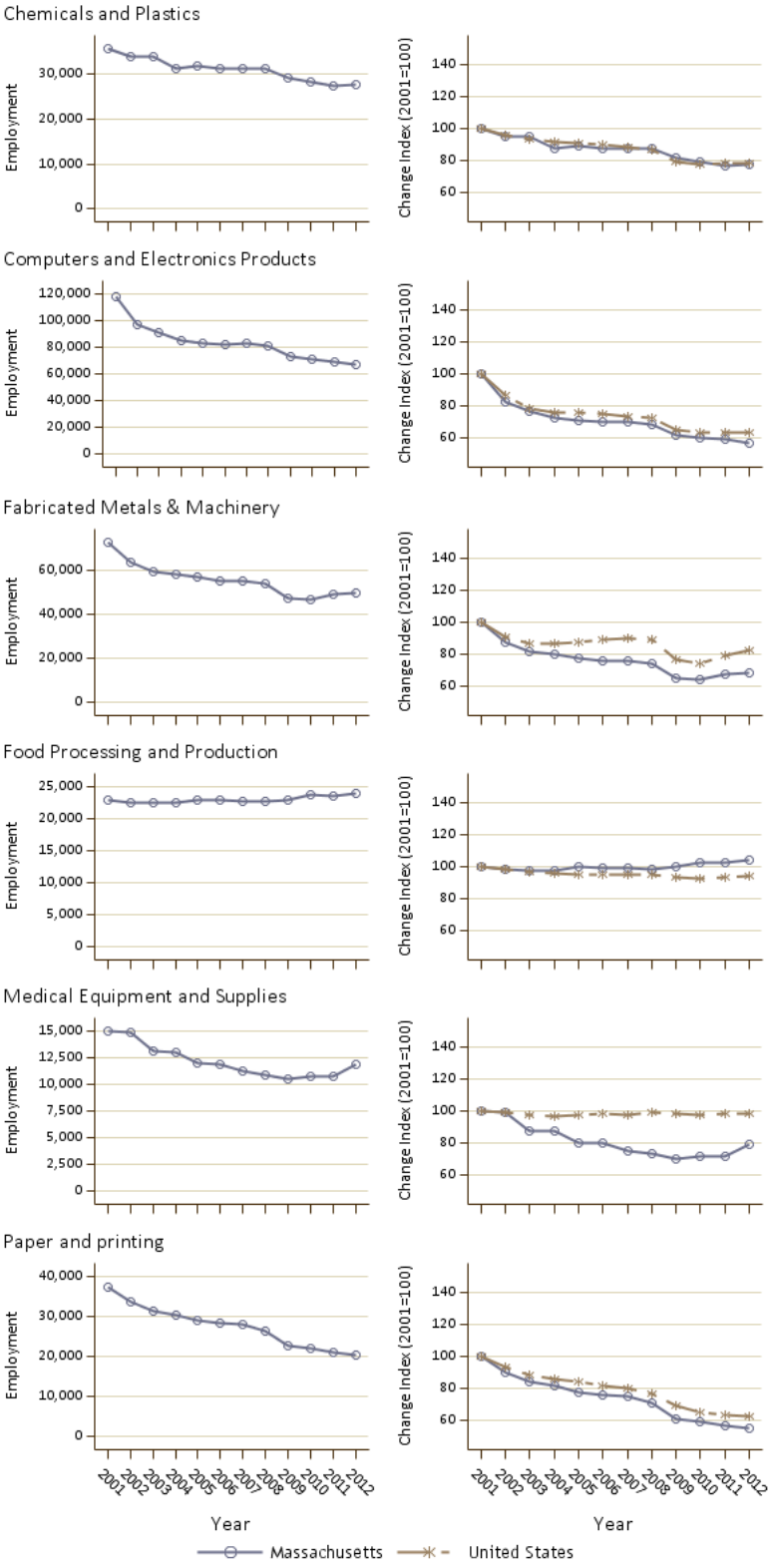
Source: Massachusetts Department of Labor, Quarterly Employment and Wages (ES-202), Author's calculations

ployment concentrated in two regions—Boston MetroWest and the Northeast (Figure 9). Along with Central Massachusetts, the Northeast and Boston MetroWest regions also have notably higher share of the regional employment base in Computers and Electronics compared to the nation (Figure 10).

Computers and electronics experienced the greatest job losses of any sector—losing nearly half of its employment base since 2001. As shown in Figure 11, this subsector faced a particularly steep drop in employment between 2001 and 2003 in the wake of the 'dotcom' market crash of the early 2000s. Employment stabilized after 2005, but was hit again by the Great recession in 2008. The subsector has experienced a consistent, but slight, decline in the years since. Overall, these trends largely mirror the subsectors performance at the national scale, and are not likely due to any particular regional deficiency.

Despite these job losses, wage growth within this subsector has been rather robust. In 2012, its workers earned an average of $114,801 — by far the highest wage level of all the subsectors. This represents a real dollar increase of nearly $20,000 per work since 2001. The highest wages are paid in the Boston MetroWest, Northeast, and Central regions—regions where the industry is most heavily concentrated (Figure 12). These same regions also experienced the most robust wage growth over the past twelve years. The remaining regions all lag behind the national average for the subsector. The Berkshires experienced a fairly dra-

Figure 11
Employment Change by Advanced Manufacturing Subsector



Source: Massachusetts Department of Labor, Quarterly Employment and Wages (ES-202), Author's calculations

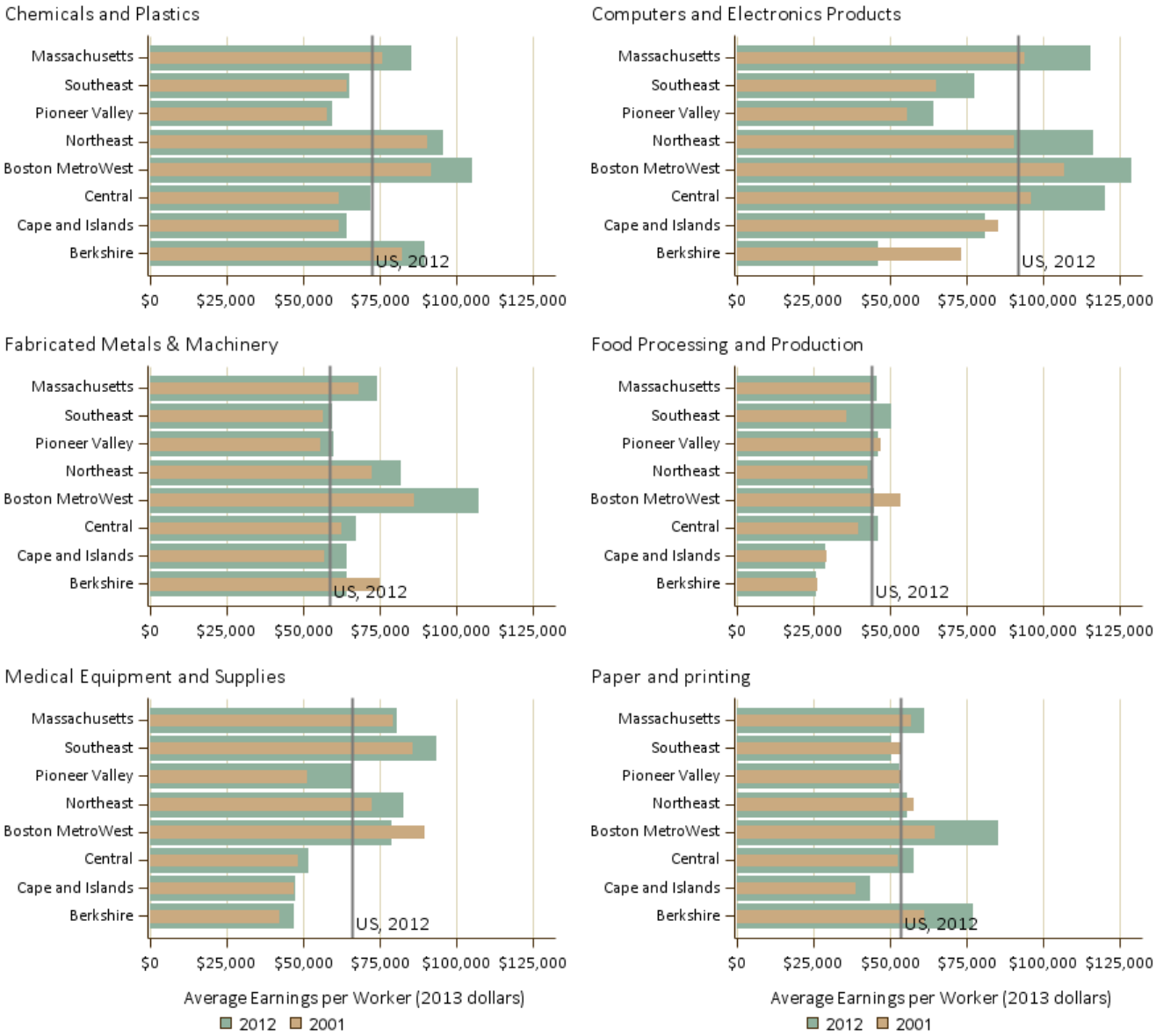
matic decline of nearly $27,000 in real earnings per worker since 2001. But Computer and Electronics employers in the Berkshires are relative few. As such dramatic changes are not uncommon and may possibly be the result of layoffs from a single, or small number, of larger employers.

Fabricated Metals and Machinery

Fabricated Metals and Machinery is the second largest subsector with roughly 50,000 workers as of 2012 (Table 3). It also has the largest number of establishments of any subsector. Most are relatively small, averaging just over 25 workers per establishment. Employment in this subsector is fairly well dispersed throughout the state. The Northeast region has the largest Fabricated Metals workforce, but the subsector is most heavily concentrated in the Pioneer Valley and Central regions given their size (Figures 9 and 10).

Similar to the Computers and Electronics Products subsector, Fabricated Metals and Machinery also suffered most of its nearly 23,000 net job losses in the early portions of the 2000's and in the aftermath of the Great Recession

Figure 12
Average Earnings per Worker, by Subsector and Region



Source: Massachusetts Department of Labor, Quarterly Employment and Wages (ES-202), Author's Calculations

(Figure 11). Unlike the nation as a whole, Fabricated Metals and Machinery producers in the Commonwealth did not add net new jobs during the middle portion of the decade, although there were some signs of gains since 2010.

In 2012, the Fabricated Metals and Machinery subsector paid roughly $74,000 per worker. However, this average is somewhat skewed by the Boston MetroWest and the Northeast region—both of which are notably higher, presumably due to the urban wage premium (Figure 12). Wage levels in most other regions

are either at or just above the national average of $58,000. The Boston MetroWest and Northeast regions also posted the highest real wage increases since 2001. Otherwise, most regions saw modest gains in earnings per work , ranging from $3,000 in the Southeast to just over $7,000 in the Cape and Islands. The Berkshires was the only region to see real wage reductions in the Fabricated Metals and Machinery subsector since 2001, coinciding with a rather staggering loss of just over 1,600 jobs. Despite this, average earnings in the Berkshires still remain just above the national average for this subsector.

Food Processing and Production

Of the six subsectors in Advanced Manufacturing, Food Processing and Production was the only subsectors that posted net job gains from 2001 to 2012 (Table 3). It employed just over 24,000 workers in 2012; a net employment gain of 1,000 from 2001. At the same time, the number of establishments in the Food Processing subsector actually declined by 165. So while there are fewer businesses in the industry, those that remain have hired more workers and offsetting any closure-induced layoffs. Most of the employment growth in the Massachusetts Food Processing subsector occurred following the peak of the 2008 recession—consistently surpassing the nation which experienced a steady decline in employment levels during this time (Figure 11).

The regional employment distribution in Food Processing and Production largely follows overall employment patterns, suggesting much of the employment in this sector is oriented to serving local and regional markets (Figure 9). In fact, our presentation of location quotients in Figure 10 reveals that this subsector is underrepresented in nearly all regions relative to the national employment share.

But while job growth in the Food Processing and Production sector is a positive sign, the industry, on average, pays far less than the other subsectors within Advanced Manufacturing. There is also little regional variation in wage levels, most paying wages very close to the national average (Figure 12). The exceptions are the Berkshires and the Cape and Islands regions, which, on average, paid from 60 to 65 percent of the national rate of $43,962 per worker in 2012.

Medical Equipment and Supplies

Medical Equipment and Supplies is the smallest of the six Advanced Manufacturing subsectors examined in this study (Table 3). In 2012, this subsector had nearly 12,000 employees, 85% of which are located in

the Southeast, Boston MetroWest and Northeast (Figure 9). Despite its modest size, this subsector is one of the most heavily specialized to the Commonwealth with its share of the state employment base nearly 1.5 times the national share. The Medical Equipment and Supplies sector is a particular important component of the Southeast region economy, where its employment share is nearly 3 times the nation's (Figure 10).

Medical Equipment and Supplies suffered a net reduction of just over 3,000 jobs during the past twelve years, a loss equivalent to 20 percent of its 2001 employment base. These losses were heaviest in the Boston MetroWest, Northeast, and Southeast regions—where its workforce is most heavily concentrated. Regular annual job losses were a consistent feature of the industry throughout most of the 2000's (Figure 11). Although there is at least some initial evidence of a possible rebound after 2010. This contrasts with national employment trends, which have essentially remained flat since 2001.

Medical Equipment workers in Massachusetts make considerably more than their national counterparts. The statewide average of roughly $80,000 per worker is compares quite favorably to the national average of $65,746. Real wages are even higher in the Southeast ($93,000 per worker), where the subsector is the most heavily concentrated (Figure 12). The Boston MetroWest and Northeast regions also pay above the national industry average, while employers in the Central, Cape and Islands, and Berkshire regions pay considerably less.

Paper and Printing

With just over 20,000 employees in 2012, Paper and Printing is the second smallest of the six Advanced Manufacturing subsectors (Table 3). It is also the smallest subsector in terms of establishment size, averaging 24.3 workers per establishment. Like the Computers and Electronics Products subsector, Paper and Printing experienced substantial job losses in recent years, losing roughly 45% of its employment base since 2001. Job losses were fairly steady over the past twelve years, with a notable, but temporary, acceleration of loss during the peak of the Great Recession in 2008 (Figure 11). The Paper and Printing subsector has also been steadily losing jobs at the national level, although the pace of decline is generally slower than in Massachusetts.

The subsector is fairly well represented in the six regions spanning the Commonwealth The Northeast region has the largest number of Paper and Printing employees (Figure 9). The Pioneer Valley, Central, Boston MetroWest and Southeast regions are not far behind, each with over 3,200 employees in 2012. The

Berkshires region has the largest relative concentration of its employment base working in the Paper and Printing subsector—nearly 3.4 times the national share in 2012 (Figure 10). This is despite having lost more than half its employment base in the industry since 2012. The Pioneer Valley and Central regions also have high employment specializations in Paper and Printing manufacturing, both close to two times the expected national employment share. Like the Berkshires, the Pioneer Valley also lost nearly half its Printing and Paper jobs since 2001.

The Paper and Printing subsector tends to pay less than most other Advanced Manufacturing sectors at $60,923 per worker per year—just below the Commonwealth overall average of $ 62,111 but higher than the national average of $53,294 for the industry. Most regions pay earnings close to the national wage (Figure 12). The exceptions are the Boston MetroWest region and the Berkshires, where workers make an average over $70,000 per year.

Occupational Profile of the Advanced Manufacturing Subsectors

In this section we identify the "core" occupations for each of the six Advanced Manufacturing subsectors to help us better understand labor force challenges and training needs. We examine current statistics on employment for these core occupations to help anticipate near-future demand for new workers as well as the training needs of employers. For industries facing major declines, occupational employment levels can also help us to anticipate, and possibly help mitigate, the impacts of future layoffs and dislocations. We also compare wages and wage growth across subsectors and over time. Wages are typically used as an indicator of occupational skill levels as well as relative scarcity of workers in certain fields. Comparing the prevailing wages of each occupation in the sector to the overall average for the occupation, can also help identify areas where recruitment efforts may be difficult, such as in cases where a subsector pays far less than others for the same types of workers.

We define core occupations by the number of workers in the subsector and whether the occupation is relatively specific to Advanced Manufacturing. The latter criterion leads us to drop occupations with general skills, allowing us to focus on occupations with the types of specialized skills needed by Advanced Manufacturing companies. Because they are specialized, these skills are also likely to be in relatively short supply in the general labor force. Consider Table 4, which shows employment within major occupational groups within Advanced Manufacturing. Workers within Massachusetts' Advanced Manufacturing sector span the occupational spectrum, with the largest number found in production occupations. Architecture and engineering related occupations make up the second largest group, reflecting the industry's reliance on engineers, engineering technicians, and designers. Both these occupational groups are also at somewhat concentrated/specialized to Advanced Manufacturing. The Advanced Manufacturing sector employs roughly 75% of all workers in production occupations and nearly 35% of all architecture and engineering workers—both quite large shares considering that Advanced Manufacturing only represents a little over 5% of the state's entire occupational labor force. By contrast, consider the "office and administration support and sales and related" group. Advanced Manufacturing companies hire many of these types of workers as well—but so do most other industries. Only 4.5% of office and administrative support workers in the state work in Advanced Manufacturing. Broadly speaking, a manufacturer looking to hire for an administrative support position typically has a deeper pool to draw from because the necessary skills are common and generally transferrable across industries. There are also typically an abundance of educational and training programs directed to these common occupations, requiring little intervention by the workforce development system. We proceed with a brief discussion of the core occupations for each subsector.

Table 4
Major Occupational Groups within Advanced Manufacturing, 2012

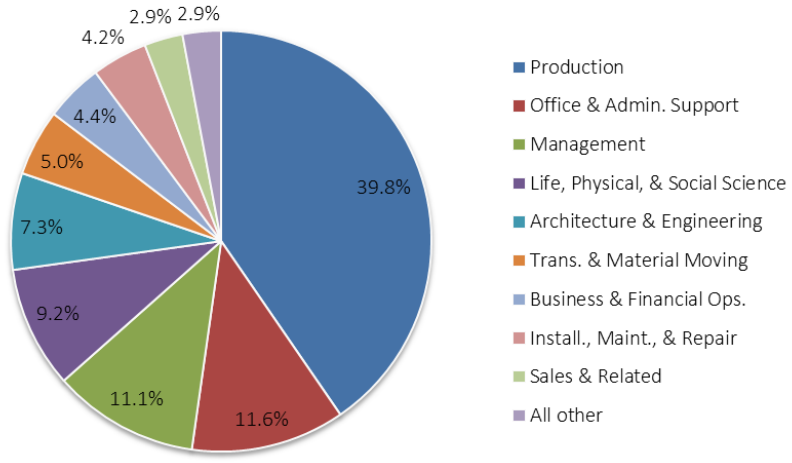
SOC	Occupational Category	Total Number	Ind Share	Occ Share
51-0000	Production Occupations	65,540	37.7%	75.3%
17-0000	Architecture and Engineering Occupations	17,810	10.2%	34.7%
43-0000	Office and Administrative Support Occupations	16,950	9.7%	4.5%
11-0000	Management Occupations	16,520	9.5%	10.4%
41-0000	Sales and Related Occupations	7,580	4.4%	2.7%
53-0000	Transportation and Material Moving Occupations	6,630	3.8%	6.0%
13-0000	Business and Financial Operations Occupations	6,050	3.5%	4.4%
15-0000	Computer and Mathematical Occupations	4,140	2.4%	3.4%
49-0000	Installation, Maintenance, and Repair Occupations	3,540	2.0%	9.3%
19-0000	Life, Physical, and Social Science Occupations	2,770	1.6%	16.0%
35-0000	Food Preparation and Serving Related Occupations	1,650	0.9%	1.3%
27-0000	Arts, Design, Entertainment, Sports, and Media Occupations	910	0.5%	10.2%
37-0000	Building and Grounds Cleaning and Maintenance Occupations	860	0.5%	1.6%
47-0000	Construction and Extraction Occupations	420	0.2%	2.9%
23-0000	Legal Occupations	140	0.1%	0.8%
29-0000	Healthcare Practitioners and Technical Occupations	60	0.0%	5.1%
00-0000	All Occupations*	173,980	100.0%	5.4%

*Source: US BLS, Occupational Employmet Series Research Estimates by Industry and State & OES, author's calculations.*The sum of occupational categoriesdoes not equate to the ALL Occupational total due to data suppression. See methodology.*

Chemicals and Plastics

The Chemical and Plastics subsector carries out a wide range of activities in a number of areas related to science, engineering and production. Approximately 40% of all workers in the subsector are in production occupations, which is slightly lower than the 47% average for Advanced Manufacturing as whole (Figure 13). Chemicals and Plastics has a higher share of workers in science (9.2%) and engineering (7.3%) occupations than commonly found in other sec-

Figure 13
Chemicals and Plastics Employment by Major Occupation Group



Source: US BLS, Occupational Employment Series Research Estimates by Industry and State

tors. About half of all workers in chemical and plastics work in one of these three major occupation groups. Another 27% are in administrative support or managerial positions.

Table 5 identifies the specific core occupations in the Chemical and Plastics sector. As expected, production, sciences, and engineering occupations dominate the ranks of the subsector's core occupations. Many of the top employing occupations involve machine operation of one type or another; including molding, coremaking and casting machine setters; mixing and blending machine setters; and extruding and drawing machine setters—all of which are also relatively specialized to this subsector. We also see high specialization among several of the core science-based occupations, specifically chemists, chemical technicians, and chemical equipment operators. In addition, several occupations stem from the biological and life sciences—although generally less specialized to this specific subsector.

Earnings in this subsector typically match the prevailing rates for the occupation across all industries (Figure 14). Key exceptions include microbiologists, who make nearly $25,000 more in this subsector than other industries. Chemists and chemical technicians make slightly more than similar workers in other industries. Biochemists and industrial engineers make notably less in Chemicals and Plastics than elsewhere, suggesting that hiring new workers to fill vacancies in these areas may be difficult at current wages.

Table 5
Chemicals and Plastics, Core Occupations, Employment and Wages in 2012 (wages reported in 2013 dollar value)

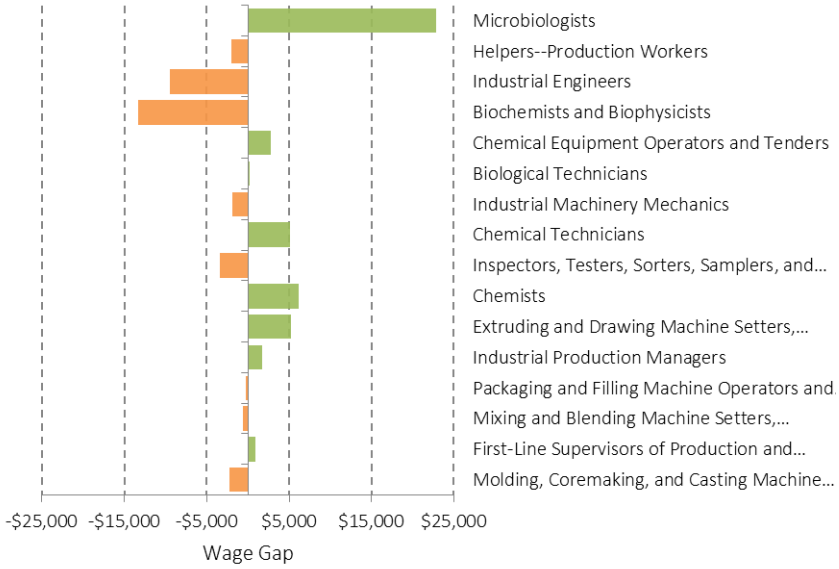
SOC	Occupational Title	Number	Ind share	Occ share	Mean Wage
51-4072	Molding, Coremaking, and Casting Machine Setters, Operators, and Tenders, Metal and Plastic	1,650	6.0%	51%	$31,159
51-1011	First-Line Supervisors of Production and Operating Workers	1,050	3.8%	9%	$65,031
51-9023	Mixing and Blending Machine Setters, Operators, and Tenders	800	2.9%	54%	$37,136
51-9111	Packaging and Filling Machine Operators and Tenders	650	2.4%	8%	$29,960
11-3051	Industrial Production Managers	640	2.3%	17%	$110,306
51-4021	Extruding and Drawing Machine Setters, Operators, and Tenders, Metal and Plastic	600	2.2%	21%	$40,277
19-2031	Chemists	570	2.1%	15%	$91,102
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	550	2.0%	7%	$38,417
19-4031	Chemical Technicians	500	1.8%	23%	$55,354
49-9041	Industrial Machinery Mechanics	440	1.6%	12%	$52,815
19-4021	Biological Technicians	400	1.5%	7%	$46,379
51-9011	Chemical Equipment Operators and Tenders	360	1.3%	47%	$47,220
19-1021	Biochemists and Biophysicists	350	1.3%	11%	$90,617
17-2112	Industrial Engineers	340	1.2%	6%	$80,627
51-9198	Helpers--Production Workers	340	1.2%	5%	$25,946
19-1022	Microbiologists	300	1.1%	18%	$97,318

Source: US BLS, Occupational Employmet Series Research Estimates by Industry and State & OES, author's calculations

Computers and Electronics

The occupational base of Computers and Electronics is somewhat more diverse than the other Advanced Manufacturing subsectors (Figure 15). Production occupations is the largest major occupational group, although it represents a far smaller share of employment in this subsector compared to others. Not surprisingly, this subsector has a much higher share of computer & mathematical and architectural & engineering occupations—areas generally requiring high levels of formal education.

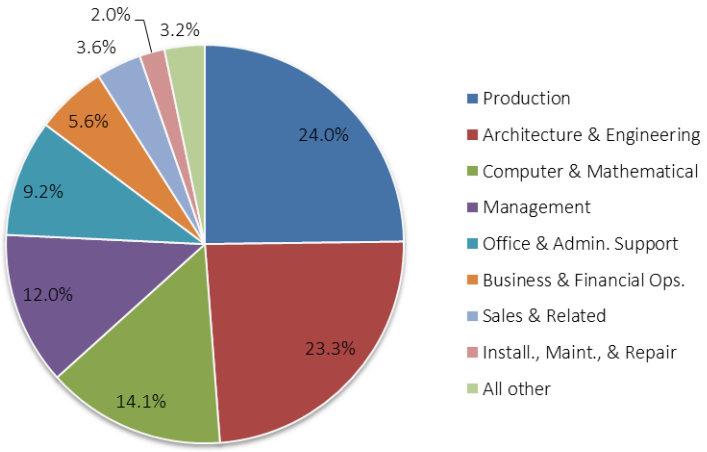
Figure 14
Difference in occupational earnings, Chemicals & Plastics v. All Industries



Source: US BLS, Occupational Employment Series Research Estimates by Industry and State

Many of the core occupations of Computers and Electronics are highly specialized to this subsector, particularly those relating to electrical equipment production, electrical engineering, and semiconductors processing (Table 6). Finding new workers to fill openings in these most specialized occupations may be difficult because the subsector cannot readily draw workers from other industries. Producers within this sector likely compete with one another for talent. Similarly, in the case of an industry-wide downturn, dislocated workers may find it difficult to transfer their skills to some other industry.

Figure 15
Computer and Electronics, Employment by Major Occupation Group



Source: US BLS, Occupational Employment Series Research Estimates by Industry and State

Wages offered by this subsector typically fall close to the average for all occupations (Figure 16). This is not surprising for highly specialized occupations, where the subsector basically dominates the occupational average. There is more variability among some of the more universal occupations. The industry seems willing to pay a premium for engineering managerial talent and line pro-

Table 6
Computer and Electronic Products, Core Occupations, Employment and Wages in 2012

SOC	Occupational Title	Number	Ind share	Occ share	Mean Wage
51-2022	Electrical and Electronic Equipment Assemblers	4,530	6.8%	68%	$34,290
17-3023	Electrical and Electronics Engineering Technicians	3,040	4.6%	50%	$57,081
17-2071	Electrical Engineers	1,960	2.9%	26%	$102,294
17-2141	Mechanical Engineers	1,840	2.8%	22%	$94,093
17-2112	Industrial Engineers	1,630	2.4%	27%	$91,395
15-1133	Software Developers, Systems Software	1,620	2.4%	6%	$112,027
11-9041	Architectural and Engineering Managers	1,480	2.2%	23%	$160,559
51-2023	Electromechanical Equipment Assemblers	1,430	2.1%	49%	$38,625
51-2092	Team Assemblers	1,390	2.1%	9%	$33,538
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	1,280	1.9%	15%	$39,572
17-2072	Electronics Engineers, Except Computer	1,260	1.9%	25%	$102,757
51-1011	First-Line Supervisors of Production and Operating Workers	1,190	1.8%	11%	$69,398
15-1132	Software Developers, Applications	930	1.4%	3%	$105,246
51-9141	Semiconductor Processors	910	1.4%	100%	$36,990
17-2061	Computer Hardware Engineers	890	1.3%	24%	$109,480
17-3026	Industrial Engineering Technicians	860	1.3%	28%	$54,349
51-4041	Machinists	790	1.2%	9%	$49,735
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	670	1.0%	26%	$46,124

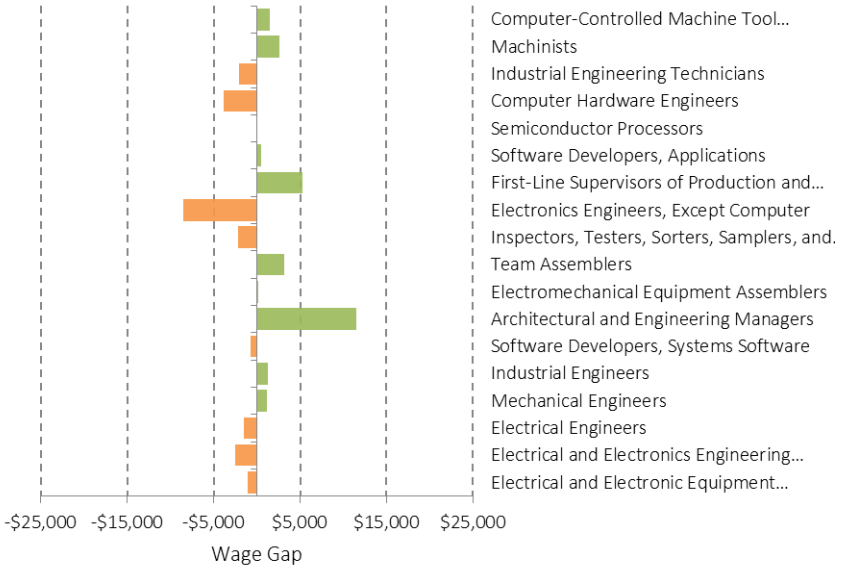
Source: US BLS, Occupational Employmet Series Research Estimates by Industry and State & OES, author's calculations

duction supervisors. It seems to be less inclined to pay competitive wages for electronics engineers who do not have a computers background.

Fabricated Metals and Machinery

Fabricated Metals and Machinery has the highest concentration of production workers of all subsectors in Advanced Manufacturing (Figure 17). Over half its workforce are in production-related occupations, specifically workers that use machining, tools, and other tangible processes to complete work. The subsector also hires a respectable number of engineering-

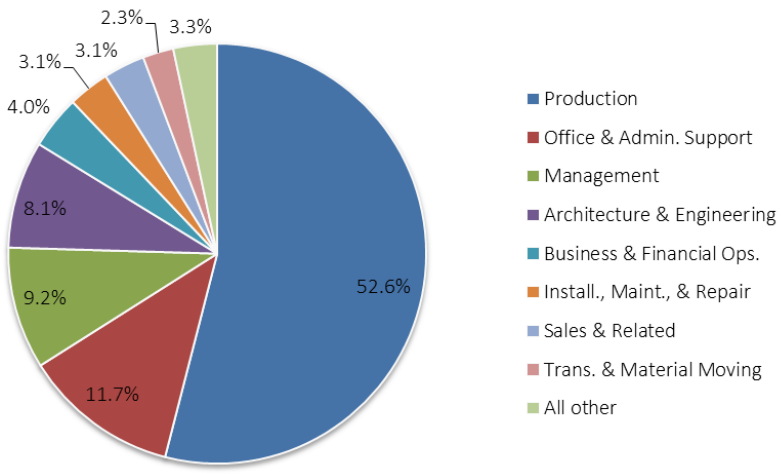
Figure 16
Difference in occupational earnings, Computer & Electronics v. All Industries



Source: US BLS, Occupational Employment Series Research Estimates by Industry and State

related workers, representing about 9% of total occupations. This category contains occupations that design products and production processes. The remaining occupations fall into more ubiquitous categories typically present in many industries such as business operations, administrative, management, and sales related work. There are relatively few natural and life sciences workers in this subsector.

Figure 17
Fabricated Metals and Machinery Employment by Major Occupation Group



Source: US BLS, Occupational Employment Series Research Estimates by Industry and State

Core occupations in the sector are highly oriented towards machining and tool operators (Table 7). About 9% of all occupations in the Fabri-

Table 7
Fabricated Metals and Machinery, Core Occupations, 2012 Employment and Wages

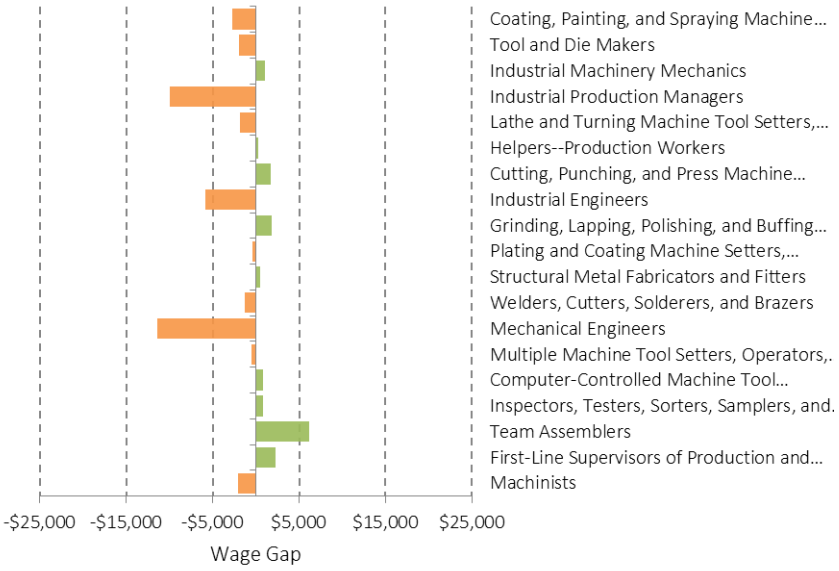
SOC	Occupational Title	Number	Ind share	Occ share	Mean Wage
51-9121	Machinists	4,630	9.2%	50.9%	$45,094
51-4111	First-Line Supervisors of Production and Operating Workers	2,150	4.3%	19.1%	$66,446
49-9041	Team Assemblers	1,590	3.2%	9.8%	$36,518
11-3051	Inspectors, Testers, Sorters, Samplers, and Weighers	1,540	3.1%	18.2%	$42,546
51-4034	Computer-Controlled Machine Tool Operators, Metal and Plastic	1,420	2.8%	55.0%	$45,399
51-9198	Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic	1,150	2.3%	49.1%	$35,750
51-4031	Mechanical Engineers	1,080	2.2%	13.1%	$81,516
17-2112	Welders, Cutters, Solderers, and Brazers	1,030	2.1%	37.2%	$45,072
51-4033	Structural Metal Fabricators and Fitters	940	1.9%	55.3%	$43,819
51-4193	Plating and Coating Machine Setters, Operators, and Tenders, Metal and Plastic	840	1.7%	73.0%	$34,342
51-2041	Grinding, Lapping, Polishing, and Buffing Machine Tool Setters, Operators, and Tenders	690	1.4%	38.8%	$40,480
51-4121	Industrial Engineers	660	1.3%	10.8%	$84,189
17-2141	Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic	610	1.2%	23.5%	$35,450
51-4081	Helpers--Production Workers	600	1.2%	9.3%	$28,187
51-4011	Lathe and Turning Machine Tool Setters, Operators, and Tenders, Metal and Plastic	580	1.2%	59.8%	$47,079
51-9061	Industrial Production Managers	570	1.1%	15.5%	$98,668
51-2092	Industrial Machinery Mechanics	530	1.1%	13.9%	$55,737
51-1011	Tool and Die Makers	510	1.0%	40.5%	$48,627
51-4041	Coating, Painting, and Spraying Machine Setters, Operators, and Tenders	500	1.0%	37.6%	$32,845

Source: US BLS, Occupational Employmet Series Research Estimates by Industry and State & OES, author's calculations

cated Metals subsector are machinists, representing roughly 51% of all machinists in the state. Another 12-14% of the workforce cover varying types of machine setters and tooling specialists, most of which are also highly specialized in this sector. Production line workers and supervisors, quality control specialists, metals fabricators, and mechanical and industrial engineers also comprise a significant percentage of employment.

Workers in the Fabricated Metals subsector earn wages roughly on a par with occupational averages (Figure 18). The highest paying among our core occupations are industrial production managers, mechanical engineers, and industrial engineers—although these are also three occupations where wages are far below their respective occupational means.

Figure 18
Difference in occupational earnings, Fabricated Metals v. All Industries

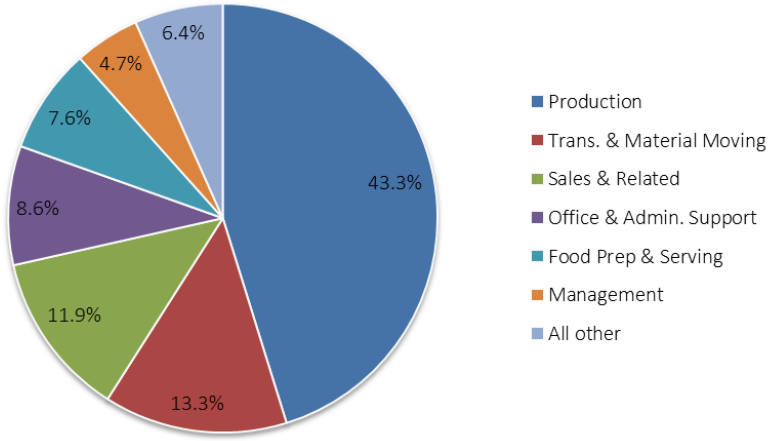


Source: US BLS, Occupational Employment Series Research Estimates by Industry and State

Food Processing and Production

Occupations in the Food Processing and Production subsector are a fairly diverse mix; at times characteristic of other forms of manufacturing and at times more akin to food services and sales (Figure 19). Forty three percent of Food Processing occupations are in production activities, with transportation and material moving and sales occupations accounting for an additional 25%. Unique to all of the Advanced Manufacturing subsectors, food preparation and serving represents a major occupational group.

Figure 19
Food Processing and Production Employment by Major Occupation Group



Source: US BLS, Occupational Employment Series Research Estimates by Industry and State

Table 8
Food Processing and Production, Core Occupations, 2012 Employment and Wages

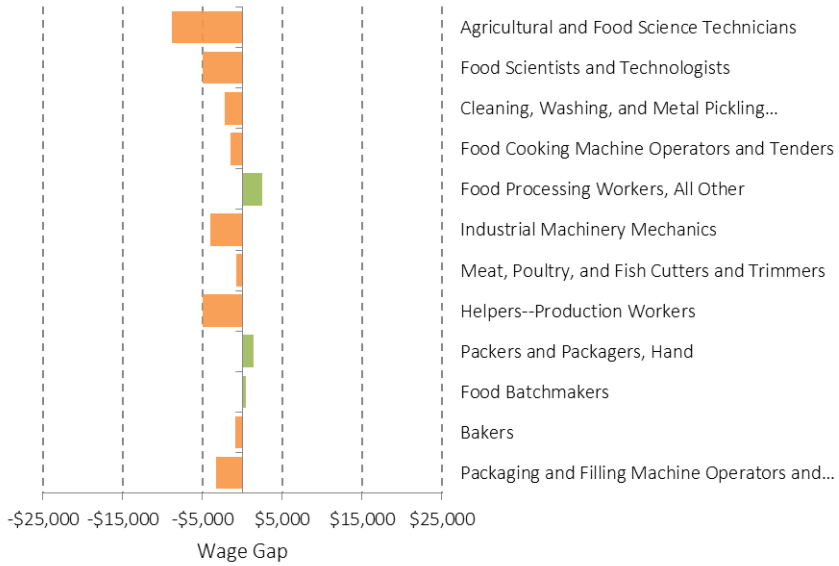
SOC	Occupational Title	Number	Ind share	Occ share	Mean Wage
51-9111	Packaging and Filling Machine Operators and Tenders	1,750	7.3%	22.6%	$26,917
51-3011	Bakers	1,640	6.9%	45.4%	$28,529
51-3092	Food Batchmakers	1,500	6.3%	76.5%	$28,527
53-7064	Packers and Packagers, Hand	890	3.7%	6.4%	$24,571
51-9198	Helpers--Production Workers	680	2.8%	10.6%	$22,945
51-3022	Meat, Poultry, and Fish Cutters and Trimmers	270	1.1%	29.0%	$30,342
49-9041	Industrial Machinery Mechanics	200	0.8%	5.3%	$50,672
51-3099	Food Processing Workers, All Other	190	0.8%	51.4%	$34,262
51-3093	Food Cooking Machine Operators and Tenders	190	0.8%	61.3%	$27,234
51-9192	Cleaning, Washing, and Metal Pickling Equipment Operators and Tenders	80	0.3%	14.3%	$28,733
19-1012	Food Scientists and Technologists	60	0.3%	31.6%	$74,067
19-4011	Agricultural and Food Science Technicians	50	0.2%	29.4%	$34,109

Source: US BLS, Occupational Employmet Series Research Estimates by Industry and State & OES, author's calculations

Many of the core occupations in the Food Processing and Production subsector involve industrial food preparing and processing: bakers; food batchmakers; meat, poultry and fish cutters, and food-related machinery operators (Table 8). These also tend to be the most heavily specialized to the subsector. Packaging and shipping is also a major production activity, although somewhat less specific to food production. There are few science and engineering occupations among the core, with the notable exception of food scientists and food technicians. Although relatively specialized to this subsector, they only involve a small number of workers.

Average wage and salary earnings in Food Processing and Production are notably lower than the other Advanced Manufacturing subsectors (Figure 20). This is, in part, because the industry is comprised of relatively low-wage, low-skilled occupations. But even within these occupations, wages in the Food Processing subsector are lower than

Figure 20
Difference in occupational earnings, Food Processing v. All Industries

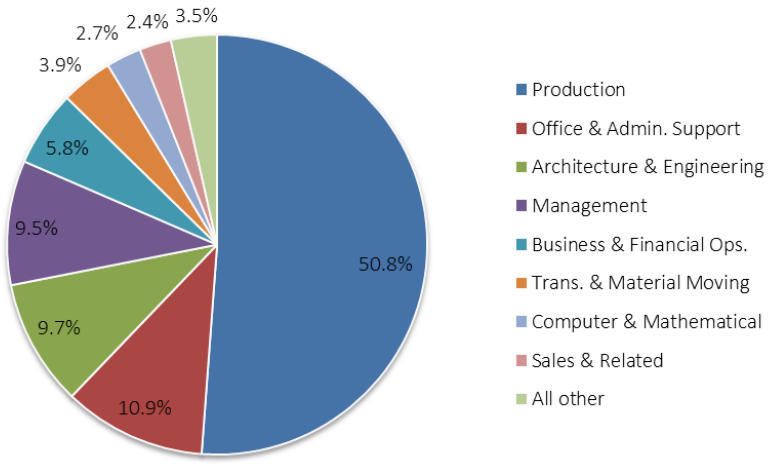


Source: US BLS, Occupational Employment Series Research Estimates by Industry and State

average, although typically by only a small amount. Food science technicians and food scientists are among those furthest below their occupational average.

Medical Equipment and Supplies

Figure 21
Medical Equipment and Supplies Employment by Major Occupation Group



Source: US BLS, Occupational Employment Series Research Estimates by Industry and State

Medical Equipment and Supplies is the smallest of the seven Advanced Manufacturing subsectors. Roughly half its workforce are in production-oriented occupations, with an additional 10% in architecture and engineering occupations (Figure 21). Otherwise, the major occupational groups found in Medical Equipment are not particularly specialized to Advanced Manufacturing.

Core occupations in Medical Equipment and Supplies are widely dispersed (Table 9). Only two are highly specialized in the sector—dental lab technicians and medical appliance technicians, which account for al-

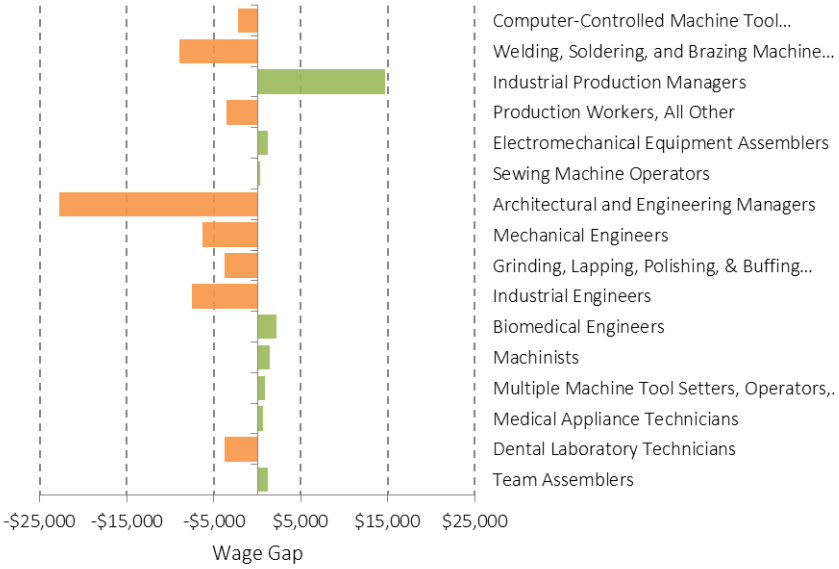
Table 9
Medical Equipment and Supplies, Core Occupations, 2012 Employment and Wages

SOC	Occupational Title	Number	Ind share	Occ share	Mean Wage
51-2092	Team Assemblers	1,420	11.9%	8.8%	$31,549
51-9081	Dental Laboratory Technicians	540	4.5%	81.8%	$50,031
51-9082	Medical Appliance Technicians	440	3.7%	75.9%	$42,789
51-4081	Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic	410	3.4%	17.5%	$37,046
51-4041	Machinists	400	3.4%	4.4%	$48,583
17-2031	Biomedical Engineers	310	2.6%	17.8%	$100,225
17-2112	Industrial Engineers	300	2.5%	4.9%	$82,538
51-4033	Grinding, Lapping, Polishing, & Buffing Machine Tool Setters, Ops, & Tenders	270	2.3%	15.2%	$34,904
17-2141	Mechanical Engineers	180	1.5%	2.2%	$86,669
11-9041	Architectural and Engineering Managers	170	1.4%	2.7%	$126,286
51-6031	Sewing Machine Operators	170	1.4%	6.1%	$24,643
51-2023	Electromechanical Equipment Assemblers	150	1.3%	5.2%	$39,647
51-9199	Production Workers, All Other	150	1.3%	6.4%	$29,906
11-3051	Industrial Production Managers	140	1.2%	3.8%	$123,349
51-4122	Welding, Soldering, and Brazing Machine Setters, Operators, and Tenders	110	0.9%	21.6%	$31,243
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	100	0.8%	3.9%	$42,422

Source: US BLS, Occupational Employmet Series Research Estimates by Industry and State & OES, author's calculations

most 1,000 workers in the sector and represent 82% and 76% of their respective occupations. The subsector shares some core occupations with the fabricated metals and machinery subsector (e.g. machine tool setters, machinists, and computer-controlled machine tool operators) and there may be opportunities for combined training efforts across both sectors. There are also a large number of engineers fields represented, including biomedical, industrial, and mechanical engineering

Figure 22
Difference in occupational earnings, Medical Equipment v. All Industries



Source: US BLS, Occupational Employment Series Research Estimates by Industry and State

Wages among the core occupations in Medical equipment can vary widely according to varying skill types and occupational activities. Workers in many core occupations make notably less than similar occupations in other industries (Figure 22). This includes some of the highest paying occupations, such as Architectural and Engineering Managers, Industrial Engineers, and Mechanical Engineers. By contrast, Industrial Production Managers make considerably higher than they do most elsewhere. Most of the Machinists and various Machine operators earn generally competitive wages compared others within their occupations.

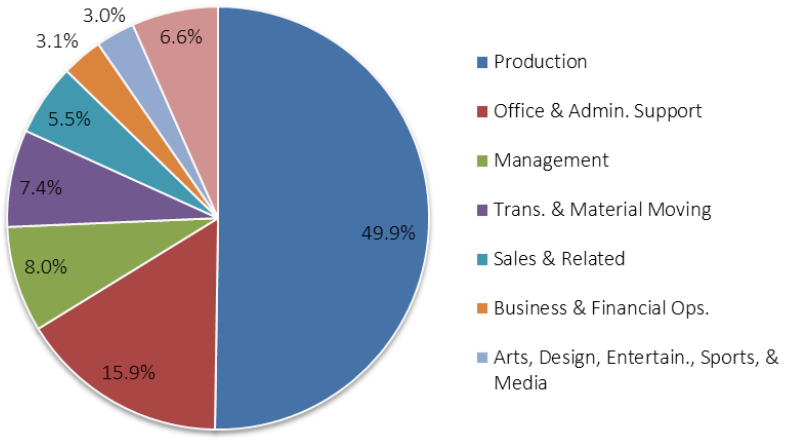
Paper and Printing

Similar to many other Advanced Manufacturing subsectors, roughly half of the occupations in Paper and Printing are production-oriented jobs supported by a large share of office, management, sales and operations support occupations that are common across numerous sectors (Figure 23). Unlike other manufacturing industries, Paper and Printing has a small, but notable, share of occupations related to arts and design —roughly 3% of all employment in the sector.

The core occupations of the sector are oriented towards printing press operations and are highly specific to paper goods and paper production (Table 10). For instance, the three largest core occupations (printing press operators, paper goods machine setters and print binding and finishing workers) make up roughly

25% of all occupations and are highly specialized to the subsector. Hence, it may be difficult to transfer dislocated workers in these sectors. However, there are a few core occupations that are common to other subsectors, such as tool and die makers, machine setters and machine feeders—offering at least some potential for cross-industry training and development opportunities.

Figure 23
Paper and Printing Employment by Major Occupation Group



Source: US BLS, Occupational Employment Series Research Estimates by Industry and State

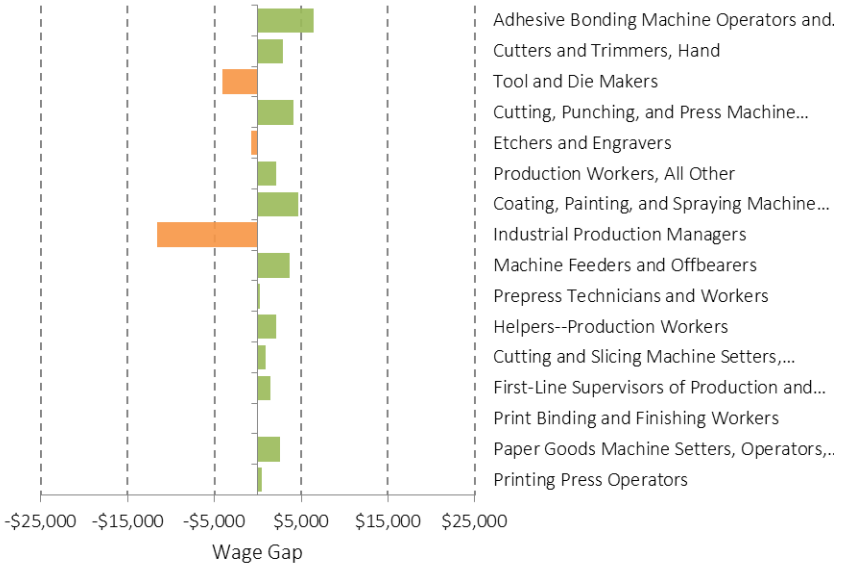
Wages among the core occupations vary widely from the highest paid (Industrial production managers, $97,035) to relatively low-skilled production occupations (Helpers, $29,976). Wages among many core occupations trend slightly higher than their respective occupational averages (Figure 24). The major exceptions are for print binding workers, etchers and engravers, prepress technicians, and printing press operators who mimic the state average— likely due to the dominance of this subsector in these

Table 10
Paper and Printing, Core Occupations, 2012 Employment and Wages

SOC	Occupational Title	Number	Ind share	Occ share	Mean Wage
51-5112	Printing Press Operators	2,390	11.2%	65.1%	$42,808
51-9196	Paper Goods Machine Setters, Operators, and Tenders	1,610	7.6%	76.7%	$37,942
51-5113	Print Binding and Finishing Workers	1,330	6.3%	90.5%	$36,927
51-1011	First-Line Supervisors of Production and Operating Workers	890	4.2%	7.9%	$65,642
51-9032	Cutting and Slicing Machine Setters, Operators, and Tenders	720	3.4%	52.6%	$37,615
51-9198	Helpers--Production Workers	710	3.3%	11.0%	$29,976
51-5111	Prepress Technicians and Workers	560	2.6%	51.9%	$42,631
53-7063	Machine Feeders and Offbearers	400	1.9%	33.1%	$33,406
11-3051	Industrial Production Managers	270	1.3%	7.4%	$97,035
51-9121	Coating, Painting, and Spraying Machine Setters, Operators, and Tenders	240	1.1%	18.0%	$40,188
51-9199	Production Workers, All Other	140	0.7%	6.0%	$35,476
51-9194	Etchers and Engravers	130	0.6%	33.3%	$35,272
51-4031	Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic	100	0.5%	3.8%	$37,822
51-4111	Tool and Die Makers	50	0.2%	4.0%	$46,532
51-9031	Cutters and Trimmers, Hand	40	0.2%	20.0%	$36,312
51-9191	Adhesive Bonding Machine Operators and Tenders	40	0.2%	16.0%	$35,170

Source: US BLS, Occupational Employmet Series Research Estimates by Industry and State & OES, author's calculations

Figure 24
Difference in occupational earnings, Paper and Printing v. All Industries



labor markets. Workers in two of the most critical cross-over occupations (industrial production managers and tool and die makers) tend to make more elsewhere.

Crossover Occupations

Thus far, our study of the occupational profile of Advanced Manufacturing has focused on core occupations, many of which tend to be highly specialized to a single or small number of subsectors. Such highly specialized occupations tend to be more highly skilled and often command fairly high wages as a result of their relatively scarce skill sets. Yet, some of the most valuable information for economic and workforce development professional is to identify occupations that are common to many subsectors. This information can help training providers develop programs that serve the needs of a greater number of employers and helps ensure that classroom seats get filled. It is also valuable in identifying similarities and complementaries in the skills base of different industries, so that workers dislocated in one may be directed to employment opportunities in another that builds upon their past experience and thus minimized the need for extensive retraining.

To identify occupations that are present in multiple Advanced Manufacturing subsectors, we identified core occupations that are, at once, present in three or more subsectors, sufficiently large (greater than 800 total workers), and relatively specialized to the Advanced Manufacturing sector (at least 30 % of total in-

Table 11

Occupations common to Multiple Advanced Manufacturing Sectors

		Advanced Manufacturing					
SOC	Occupational Title	# of subsectors	Employ-ment	Ind Share	Occ Share	Sector Ave Wage	Occ Ave Wage
51-1011	First-Line Supervisors of Production and Operating Workers	6	6,230	3.6%	55.4%	$65,401	$64,178
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	6	4,080	2.3%	48.3%	$40,316	$41,769
51-9198	Helpers--Production Workers	6	2,660	1.5%	41.3%	$26,986	$27,907
49-9041	Industrial Machinery Mechanics	6	1,520	0.9%	40.0%	$54,073	$54,652
51-2092	Team Assemblers	5	5,290	3.0%	32.7%	$33,053	$30,386
17-2112	Industrial Engineers	5	3,010	1.7%	49.4%	$87,456	$90,076
11-3051	Industrial Production Managers	5	2,350	1.4%	64.0%	$107,135	$108,599
51-4031	Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic	5	1,000	0.6%	38.5%	$35,973	$33,691
51-4041	Machinists	4	6,050	3.5%	66.5%	$45,943	$47,124
17-2141	Mechanical Engineers	4	3,230	1.9%	39.1%	$89,290	$92,942
51-9111	Packaging and Filling Machine Operators and Tenders	4	2,820	1.6%	36.4%	$28,003	$30,223
51-4011	Computer-Controlled Machine Tool Operators, Metal and	4	2,250	1.3%	87.2%	$45,141	$44,615
11-9041	Architectural and Engineering Managers	4	2,240	1.3%	35.2%	$151,556	$149,032
17-3026	Industrial Engineering Technicians	4	1,080	0.6%	35.8%	$54,729	$56,467
51-4111	Tool and Die Makers	4	860	0.5%	68.3%	$49,018	$50,612
17-3023	Electrical and Electronics Engineering Technicians	3	3,210	1.8%	52.7%	$57,116	$59,558
51-2023	Electromechanical Equipment Assemblers	3	1,980	1.1%	68.0%	$39,255	$38,434
51-4072	Molding, Coremaking, and Casting Machine Setters, Operators, and Tenders, Metal and Plastic	3	1,930	1.1%	59.2%	$31,209	$33,405
51-4081	Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic	3	1,610	0.9%	68.8%	$35,933	$36,210
51-4021	Extruding and Drawing Machine Setters, Operators, and Tenders, Metal and Plastic	3	870	0.5%	30.5%	$40,178	$35,078

Source: US BLS Occupational Employment Statistics Research Estimates by Industry and State, author's calculations.

dustry employment). These twenty "crossover" occupations are presented in Table 11. These occupations represent approximately 30% of all Advanced Manufacturing occupational employment, and include the occupations that are the most concentrated within Advanced Manufacturing. All six subsectors use line supervisors, production managers, quality control personnel, mechanics, and the somewhat generic category of production 'helpers.' The most widely needed occupations also includes many categories of engineers, engineering technicians and engineering managers, as well as a fair number of machine operators and setter of various sorts, assemblers, and machinists.

Table 12 identifies how the individual subsectors are connected through common core occupations. In general, core occupations in Fabricated Metals and Machinery sector are the most transferrable to other

Table 12

Subsector Composition of Crossover Occupations

SOC	Occupational Title	Chemicals and Plastics	Computers and Electronics	Fabricated Metals and Machinery	Food Production	Medical Equipment and Supplies	Paper and Printing
11-9041	Architectural and Engineering Managers	x	x	x		x	
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	x	x	x		x	
51-4031	Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic	x	x	x		x	x
17-3023	Electrical and Electronics Engineering Technicians		x	x		x	
51-2023	Electromechanical Equipment Assemblers		x	x		x	
51-4021	Extruding and Drawing Machine Setters, Operators, and Tenders, Metal and Plastic	x	x	x			
51-1011	First-Line Supervisors of Production and Operating Workers	x	x	x	x	x	x
51-9198	Helpers--Production Workers	x	x	x	x	x	x
17-3026	Industrial Engineering Technicians	x	x	x			x
17-2112	Industrial Engineers	x	x	x		x	x
49-9041	Industrial Machinery Mechanics	x	x	x	x	x	x
11-3051	Industrial Production Managers	x	x	x	x	x	x
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	x	x	x	x	x	x
51-4041	Machinists	x	x	x		x	
17-2141	Mechanical Engineers	x	x	x		x	
51-4072	Molding, Coremaking, and Casting Machine Setters, Operators, and Tenders, Metal and Plastic	x	x	x			
51-4081	Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic		x	x		x	
51-9111	Packaging and Filling Machine Operators and Tenders	x			x		x
51-2092	Team Assemblers		x	x	x	x	x
51-4111	Tool and Die Makers	x		x		x	x

Source: US BLS Occupational Employment Statistics Research Estimates by Industry and State, author's calculations.

subsectors. Fabricated metals has particularly close similarities to Computers and Electronics, with whom it shares 19 of the 20 crossover occupations. Fabricated metals also has strong occupational crossover with Medical Equipment and Chemicals and Plastics. In turn, Computers and Electronics is closely related to Medical Equipment (16 common occupations) and Chemicals and Plastics (14 common occupations). Food production and Paper and Printing are a bit more distinct, although closely connected to one another (16 common occupations). In the regional profiles we examine how closely these crossover occupations coincide in space.

Occupational Skills and Knowledge Requirements

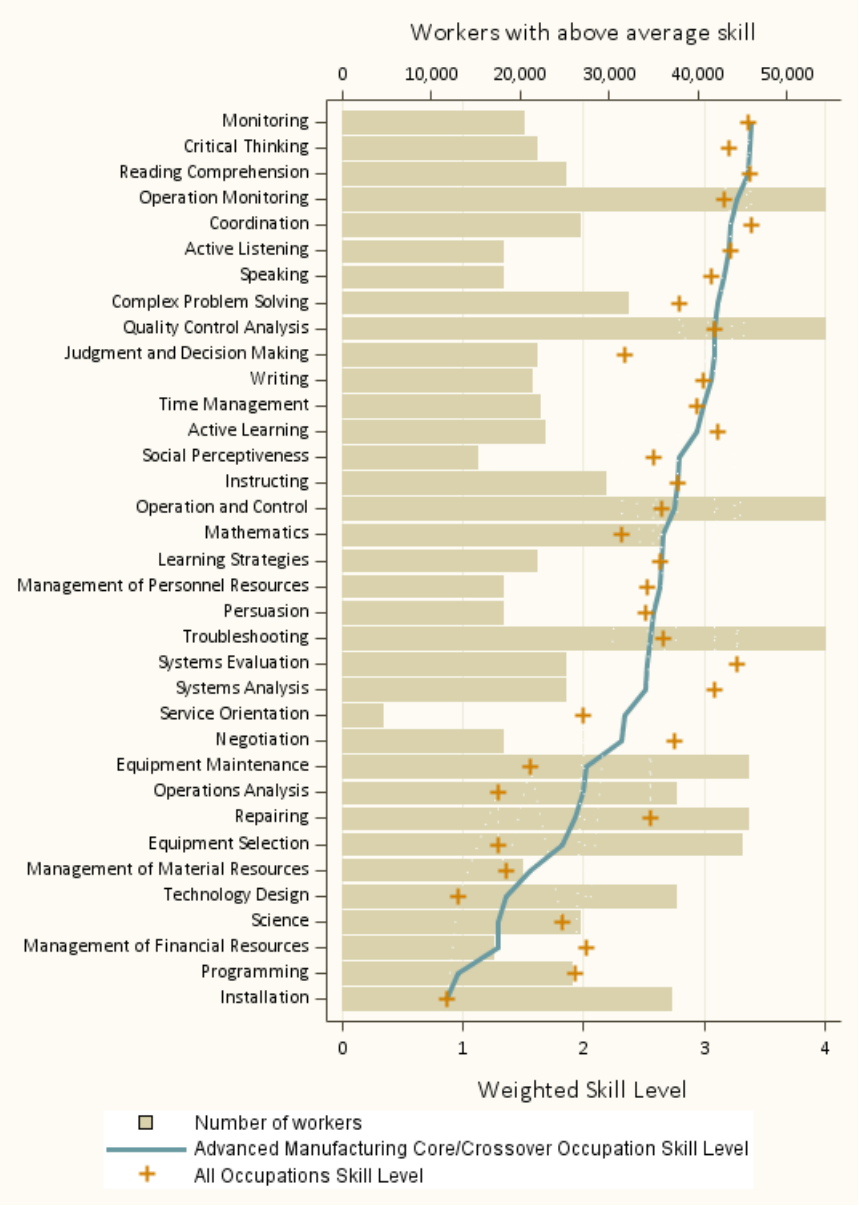
Building upon the occupational analysis, this section discusses the skill composition and requirements for the core occupations of the Advanced Manufacturing sector. This data is of particular relevance to the design and implementation of training and educational programs that target industry needs, while preparing the workforce of the future. The Bureau of Labor Statistics, Occupational Information Network (O*Net) measures occupational requirements across 35 skill domains, which are listed and defined in Appendix Table 1. These skill domains range from basic skills, such as reading, writing, and math, to skills sets that are more specific to different types of work activities, such as social skills, technical skills, and managerial skills. Each skill is rated on a one to seven scale reflecting the degree of complexity or intensity typically required by the occupation — referred to as the skill's 'level' (LV). Skills are also rated in terms of their 'importance' (IM) to the occupation. The two indicators are very closely related for most occupations, and including both is somewhat redundant. So while we report both level and importance in Appendix Table 2, the analysis that follows is based primarily on *levels* .

We begin by looking at the Advanced Manufacturing sector as a whole, focusing on the skills associated with the combined set of 20 "core" and "crossover" occupations. Figure 25 shows the number of workers in occupations requiring an above average level of each skill (the bars). We plot this against the weighted average skill level for Advanced Manufacturing's core-crossover occupations, which we compared to the average for all occupations to see where the typical sector requires a higher level of skill than other sectors.[5] So while the skill level rankings indicate the relative knowledge intensity of skills in Advanced Manufacturing, the number of workers with above average skill requirements suggests their prevalence—i.e. how many people use them with at least a moderate degree of sophistication. To help illustrate consider monitoring skills at the top of Figure 25 and installation skills at the bottom. Core/crossover occupations in the Advanced Manufacturing sector typically require a fairly high level of monitoring skills, although similar to that expected by other industries. There are just over 20,000 workers in Advanced Manufacturing occupations requiring above average monitoring skills—a small to moderate number compared to other skills. Installation skills in Advanced Manufacturing typically only require a low-level of knowledge, but there are far more workers in occupations requiring above average installation skills (approximately 37,000 workers) than monitoring skills.

[5] We weigh the skills level by the number of workers in each occupation, so that occupations with more workers count more in calculating the average skill levels.

The most common skills required of workers in Advanced Manufacturing are operation monitoring, quality control analysis, operation and control, and troubleshooting. These types of skills require attentiveness and concentration abilities as well as the ability to solve problems that do not have standard solutions. These skills are reflective of the transition of manufacturing over the last thirty years toward adaptability, flexible specialization, and non-standardized work routines. A second tier of common skills pertain to equipment—its maintenance, selection, utilization, and installation. While the relative level of knowledge required by these skills areas are fairly low—many Advanced Manufacturing workers need them and at typically higher levels than in other industries.

Figure 25
Skill requirement in Advanced Manufacturing core/crossover occupations



*Source: BLS Occupational Information Network (O*Net), 2012 BLS Occupational Employment Statistics, author's calculations.*

As further evidence of the shift to more adaptive forms of production, many of the skills with the highest level requirement are 'basic' skills that facilitate the collection and application of new information (a.k.a. learning skills). These include critical thinking, reading, listening, speaking, writing, and active learning. While not as many workers may require an above average level of these skills as operations or equipment, the levels required are typically high and generally consistent with other areas of the modern economy. Less significant to Advanced Manufacturing are socially or service oriented skills.

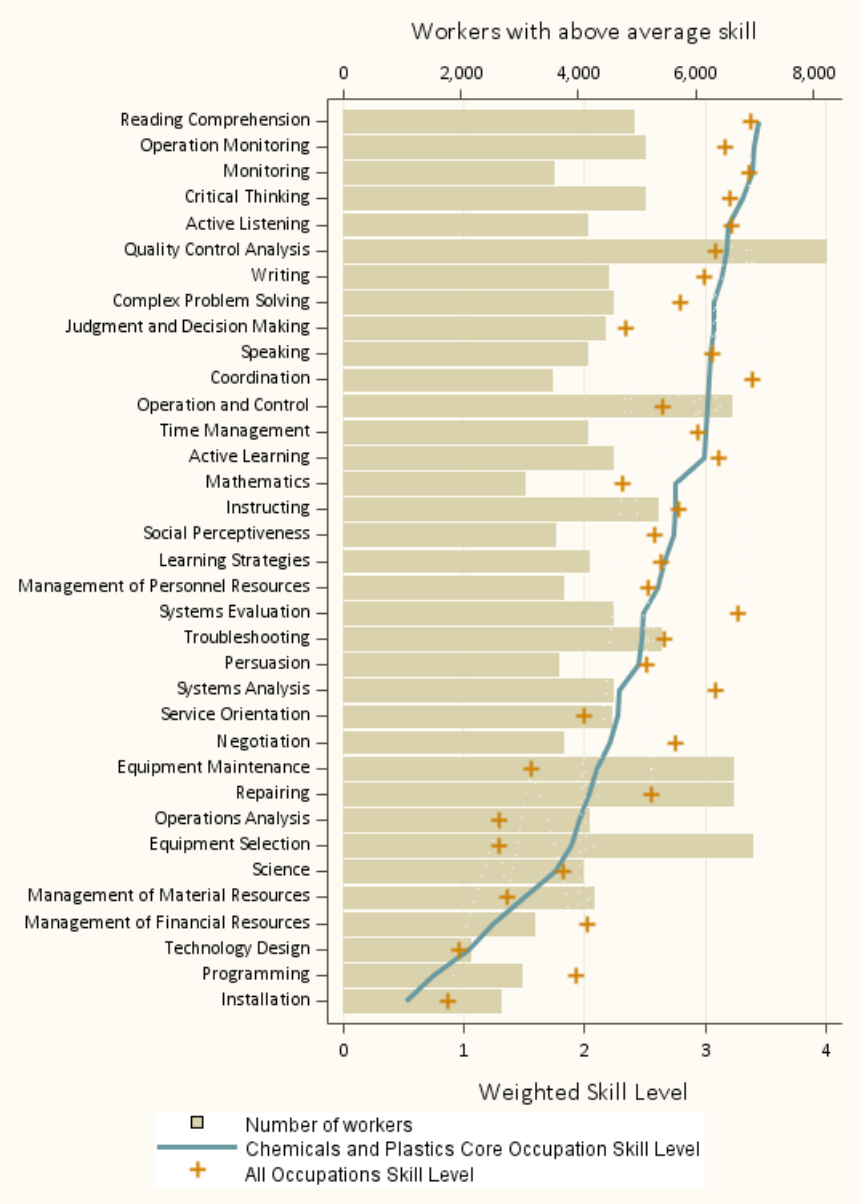
Skill requirements by subsector

This section examines similarities and differences in the relative skill requirements of the specific Advanced Manufacturing subsectors. While there are some similarities in the need and level requirements for production, operations, and basic learning skills, in general we find that skill requirements vary significantly across subsectors—based largely on the knowledge intensity and scientific content of the work. For example, workers in Computers and Electronics and Chemicals and Plastics tend to have above average requirements across numerous skills. By contrast, workers in the Food Processing and Paper and Printing sectors are required to have above average proficiency in a narrow set of skills and lower than average skills elsewhere.

Chemicals and Plastics

Characterized by a variety of science and production-oriented occupations, the skill level requirements in Chemicals and Plastics are somewhat more diverse across skill sets compared to most other subsectors. Somewhat typical of production occupations, the most prevalent skills are in the areas of quality control, equipment selection, operation and control, equipment maintenance, and repairing (Figure 26). However, workers in Chemicals and Plastics also have high requirements of basic skill sets, such as reading, critical thinking, active listening, writing,

Figure 26
Skill requirement in Chemicals and Plastics core occupations



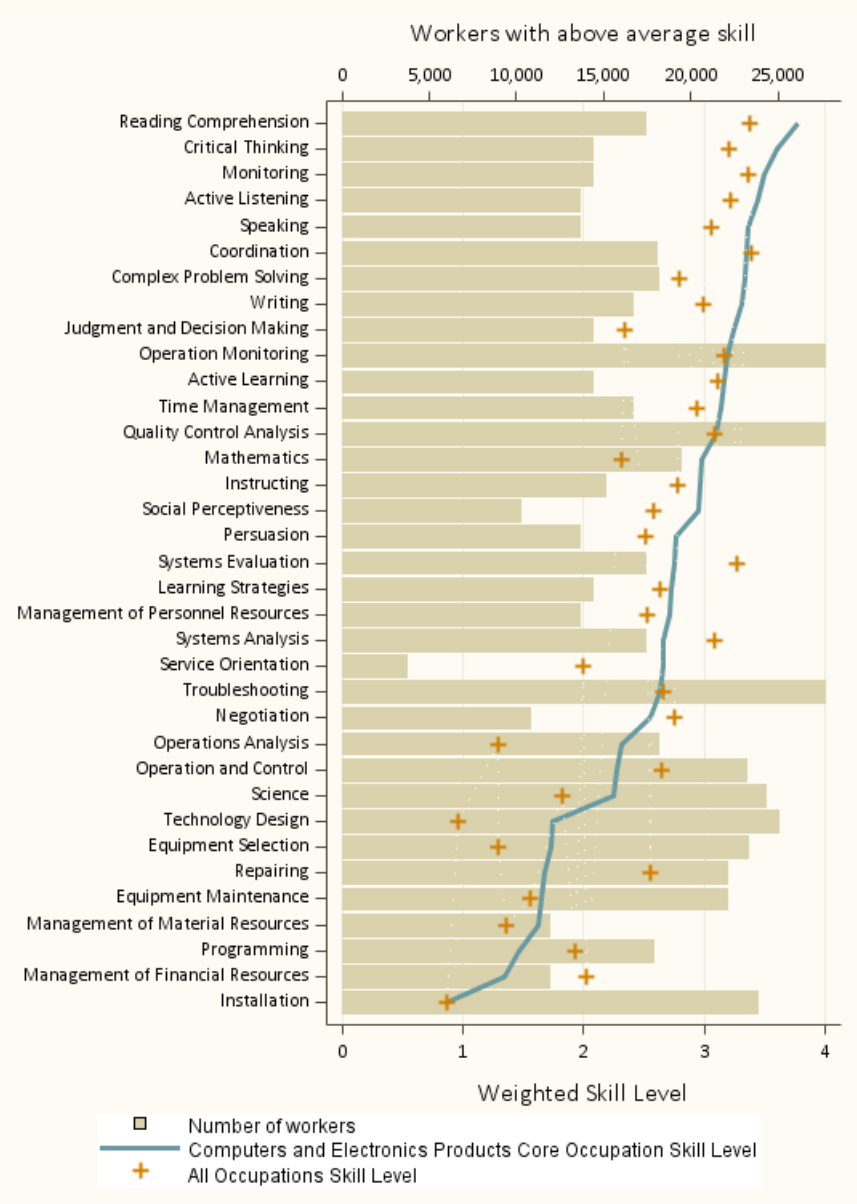
*Source: BLS Occupational Information Network (O*Net), 2012 BLS Occupational Employment Statistics, author's calculations.*

active learning, and math. The requirements for fairly high levels of basic learning skills likely reflects of the intensity of importance of innovation in this subsector, similar to Computers and Electronics and, to a lesser extent, Fabricated Metals and Machinery and Medical Equipment and Supplies.

Computers and Electronics

The core workforce of Computers and Electronics have the highest and most diverse skill requirements of the six subsectors. Its average skill levels are above the state occupational average for the vast majority of skill domains (Figure 27). Although, somewhat ironically, not in the areas often associated with computers such as systems analysis, operations and control, and programming. Similar to Chemicals and Plastics, the sector has particularly high level requirements in basic skills that facilitate the acquisition and processing of new knowledge. The most prevalent skills are in operations monitoring, quality control, troubleshooting, technology design, installation, and science. Occupations requiring an above average level of service, social perception, and interpersonal communications skills are far less common.

Figure 27
Skill requirement in Computers and Electronics core occupations

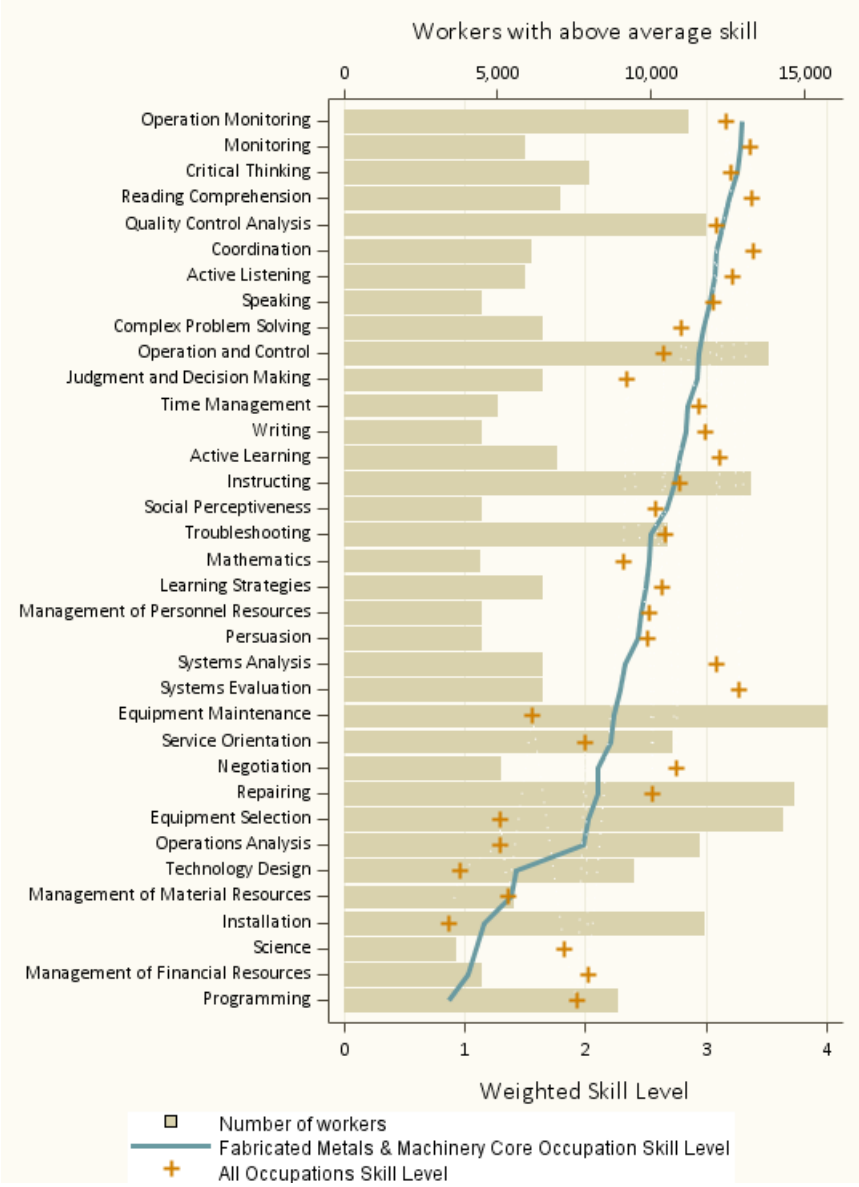


*Source: BLS Occupational Information Network (O*Net), 2012 BLS Occupational Employment Statistics, author's calculations.*

Fabricated Metals and Machinery

Fabricated Metals and Machinery ranks as the second largest subsector in Advanced Manufacturing and is a heavily production-oriented industry. The types of skills requiring high levels of knowledge are primarily technical and technological—operations monitoring, monitoring, quality control, and operations (Figure 28). A number of key decision making and information-processing skills also appear among those requiring high levels, such as critical thinking, reading comprehension, problem solving, and judgment. Regardless, the average level of skill in most domains falls just below the requirements of other industries, with notable exceptions in the areas of equipment selection, operations analysis, and technology design.

Figure 28
Skill requirements in Fabricated Metals and Machinery core occupations



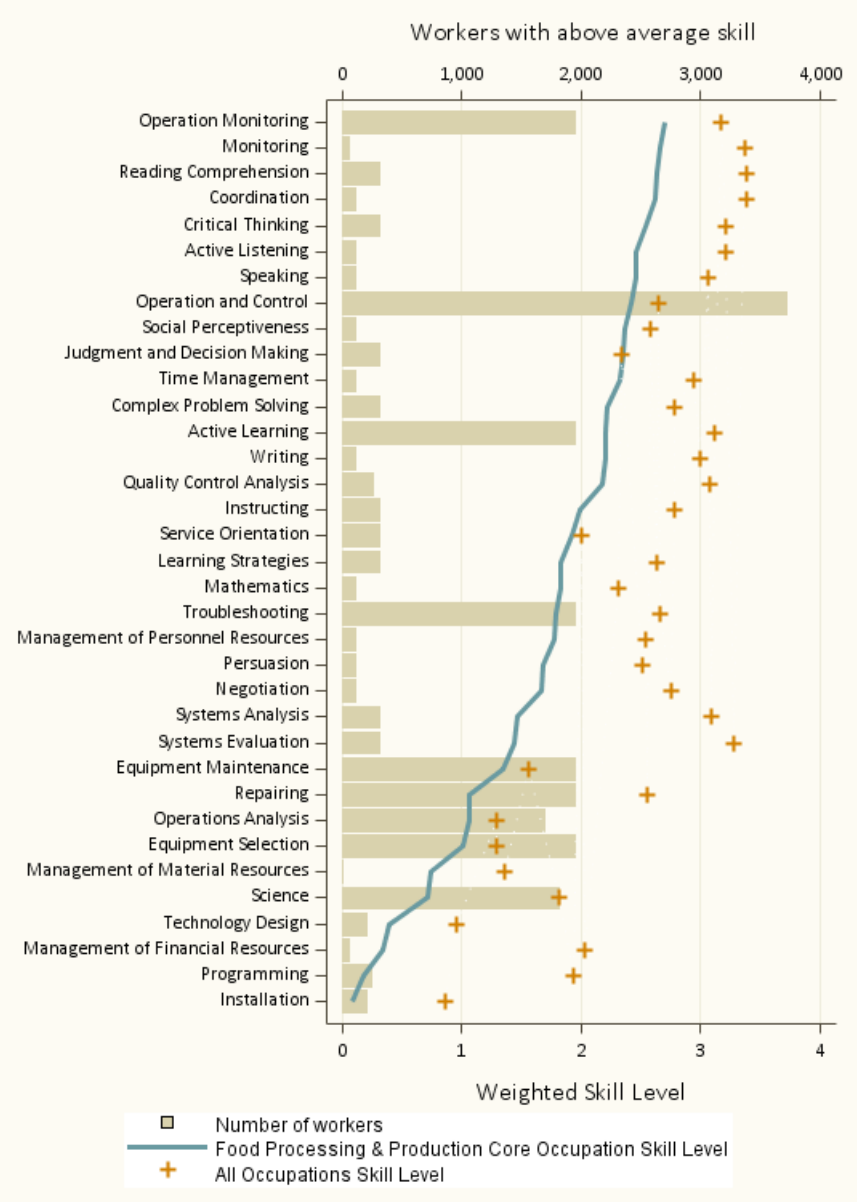
*Source: BLS Occupational Information Network (O*Net), 2012 BLS Occupational Employment Statistics, author's calculations.*

Not surprisingly, the most prevalent skills are those related to production and equipment: equipment maintenance, repairing, equipment selection, equipment selection, operation and control, and quality control analysis. Also of note is the high concentration of workers in occupations requiring an above average level of skill in instructing and service-orientation, which likely reflect an underlying culture of on-the-job training and learning by observing and doing.

Food Processing and Production

On the whole, Food Processing and Production has few high-level skill requirements, and is more characteristic of more traditional forms of low-skilled, routine forms of production than we typically associate with Advanced Manufacturing. As shown in Figure 29, the subsector is below, often far below, the average skill level requirement of other industries in just about every domain. There are also few workers in occupations requiring an above average level of skills. The most prevalent skills are in areas related to operations control and monitoring and equipment — skills common to the other Advanced Manufacturing subsectors, as well. However, the types of basic learning and complex reasoning skills found in the other subsectors are quite underrepresented in Food Processing and Production. Two noteworthy exceptions are the relative concentration of workers requiring above average skill levels in science and active learning.

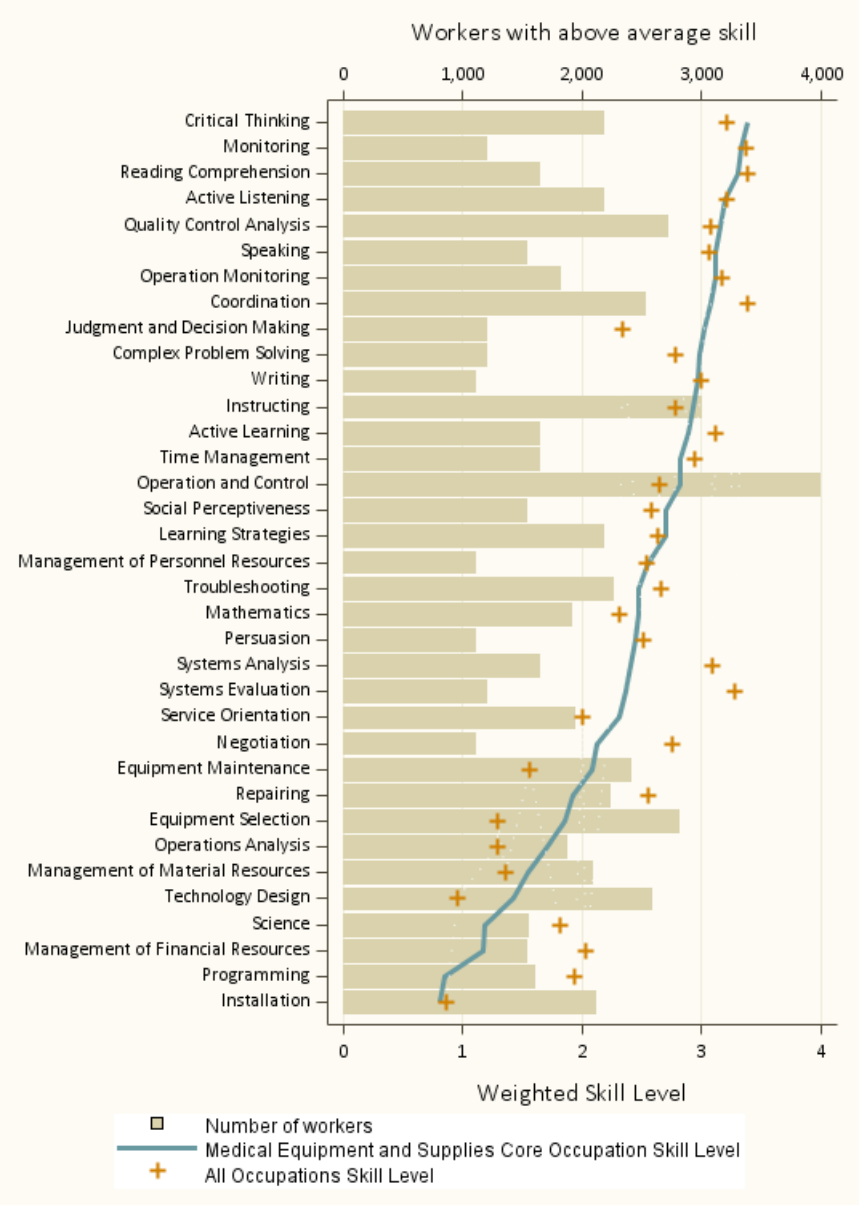
Figure 29
Skill requirements in Food Processing and Production core occupations



*Source: BLS Occupational Information Network (O*Net), 2012 BLS Occupational Employment Statistics, author's calculations.*

Medical Equipment and Supplies

Figure 30
Skill requirements in Medical Equipment and Supplies core occupations



*Source: BLS Occupational Information Network (O*Net), 2012 BLS Occupational Employment Statistics, author's calculations.*

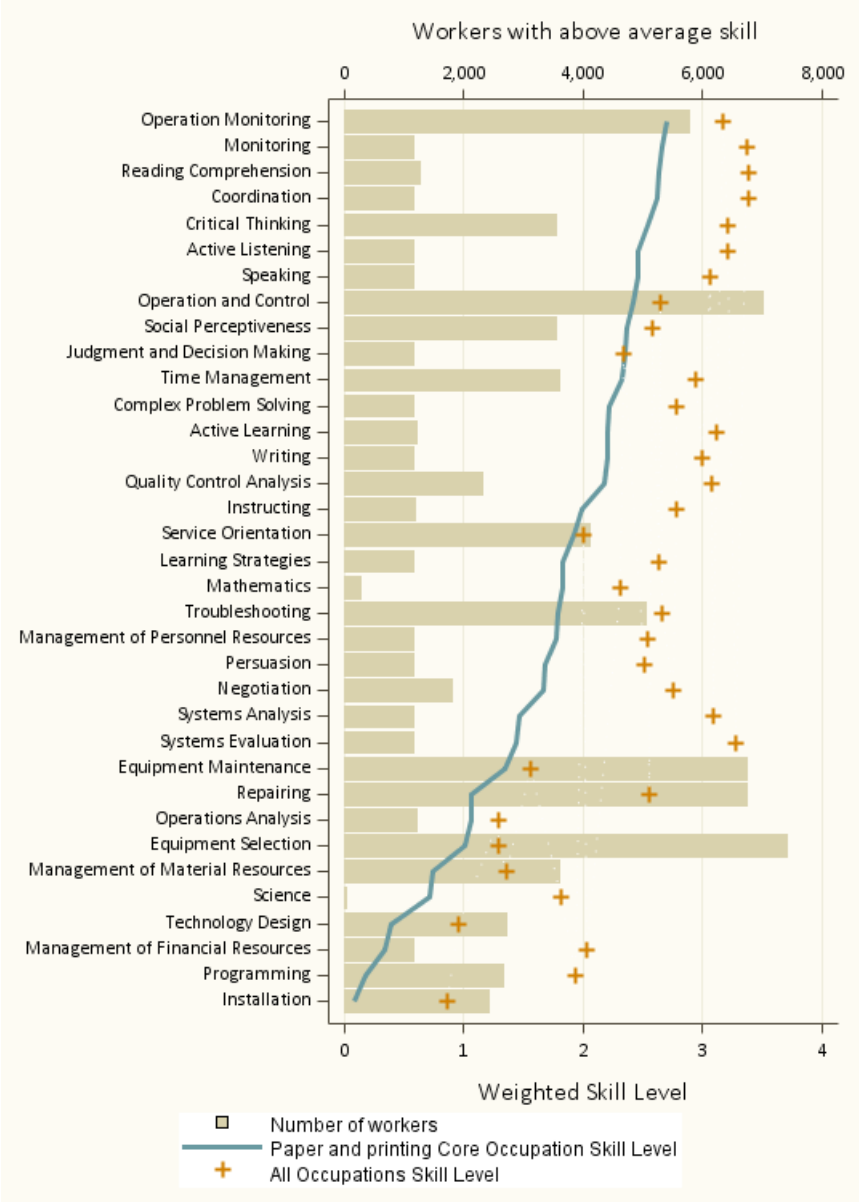
Medical Equipment and Supplies represents the smallest of the six subsectors, yet has relatively high skill requirements across a number of technical, basic, and problem solving skill domains. Critical reasoning and learning skills dominate in terms to their overall requirement levels. We also find subsector skill levels surpassing the state averages in areas such as judgment and decision making, complex problem solving, service orientation, equipment maintenance, equipment selection, and technology design. The requirements are lower than expected in areas such as systems analysis and evaluation, programming, negotiation, and science.

No single or small set of skills seem to dominate the Medical Equipment workforce. Rather, there are many workers in occupations requiring above average skill levels and the range of skills represented are quite diverse. Among the most prominent skills are operation and control, instructing, quality control, technology design, equipment selection, and coordination.

Paper and Printing

The skills profile for the Paper and Printing subsector is somewhere between what we found for Fabricated Metals and Machinery and Food Processing and Production. Like Fabricated Metals, just about half of core workers utilize production oriented skills, including equipment operation and quality control, as well as activities that help others, such a service orientation and social perceptiveness. But closer to Food Processing, we see that, in general, this is a lower-skilled subsector, with skill levels regularly falling far below statewide averages. A large share of workers are concentrated in a few specific job categories, and that is also revealed by the dominance of workers in a handful of skill domains. Communication, learning, teaching, and analysis skills are in relatively short supply. There are very few workers in occupations exceeding average skill levels in science and math.

Figure 31
Skill requirements in Paper and Printing core occupations



*Source: BLS Occupational Information Network (O*Net), 2012 BLS Occupational Employment Statistics, author's calculations.*

Experience, Education, and Training

So far, we have discussed the types of skill requirements and how they vary across Advanced Manufacturing and its subsectors. From a workforce development perspective, several significant pieces of information can be drawn from this analysis that may inform program development and discussions between stakeholders.

First, this analysis lends some corroboration to anecdotal suggestions that basic learning skills are critical to workers entering the labor force in Advanced Manufacturing. The dynamics of the industry have change significantly over the last 30 years and as such the ability of workers and industry to adapt to changing environments and flexible work flows is essential. The most successful workers are those that are able to learn and adapt as represented here by basic learning skills that facilitate knowledge absorption and processing. These skills include those aimed at problem solving and critical thinking; skills far from the traditional automated assembly line that defined years past manufacturing production processes. Yet, many of these core learning skills are gained from formal and informal means.

Second, not surprisingly workers in Advanced Manufacturing have skill requirements concentrated in technical and production oriented skills that are less abundant in the broader labor force. These include skills that have to do with process monitoring, the operation of equipment, and quality control. However, it is also apparent that workers are expected to solve problems and troubleshoot situations that may arise on the job. Many of these types of skills are gained from experience and on-the-job (OJT) and plant specific training, rather than formal educational instruction. Despite this, the modes of skill acquisition should be seen as compliments and integrated into an overall training system, particularly those that provide hands on experience and the types of technical training needed for working with advanced production machinery.

In addition to skills, we also examine four classes of worker job requirements: work experience, required level of education, on-the-job training, and on-site or in-plant training for the core occupations in Advanced Manufacturing. These are measured by the average number of years typically required as a condition of entry into the occupation (i.e. a typical job qualification) and are calculated as a weighted average of the percentages reported in the O*Net. Education is specifically measured by the approximate number of years of post-secondary (i.e. college) required.

Overall, workers in Advanced Manufacturing rely heavily on prior experience and on-the-job training to gain skills and specific knowledge. Table 13 shows the average number of years required by each of the core/crossover occupations, with highlighted cells indicating values that are greater than the average requirements for all Massachusetts occupations. Only Architecture and Engineering-related occupations surpass the average formal educational requirements of other industries, which is basically four years of college. By comparison, half of the twenty core/crossover occupations require a higher than average degree of industry-related job experience. More typically the core/crossover occupations require between 1.5 and 3 years of post-secondary education. Supervisory positions typically require the most experience, but so to

Table 13

Education, experience, and training requirements of Advanced Manufacturing core/crossover occupations (in years)

Note: Shaded areas identify occupations exceeding the average skill requirement across all occupations

SOC code	Occupation title	Education	Experience	On-the-job training	In-plant or on-site training
11-3051	Industrial Production Managers	3.90	7.50	4.78	4.73
11-9041	Architectural and Engineering Managers	6.71	9.62	5.20	4.64
17-2112	Industrial Engineers	5.44	7.45	5.17	4.93
17-2141	Mechanical Engineers	6.52	7.94	4.07	3.42
17-3023	Electrical and Electronics Engineering Technicians	4.64	8.13	4.52	4.12
17-3026	Industrial Engineering Technicians	4.63	6.37	5.04	4.10
49-9041	Industrial Machinery Mechanics	2.81	6.60	4.95	4.65
51-1011	First-Line Supervisors of Production and Operating Workers	3.47	8.61	4.65	3.84
51-2023	Electromechanical Equipment Assemblers	3.09	4.13	3.58	3.50
51-2092	Team Assemblers	2.07	2.99	2.76	2.75
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	2.28	4.64	3.60	2.43
51-4021	Extruding and Drawing Machine Setters, Operators, and Tenders, Metal and Plastic	2.10	3.46	3.43	3.04
51-4031	Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic	1.85	3.08	3.08	2.89
51-4041	Machinists	2.94	6.12	4.65	4.14
51-4072	Molding, Coremaking, and Casting Machine Setters, Operators, and Tenders, Metal and Plastic	1.94	2.90	2.48	2.28
51-4081	Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic	2.19	5.05	4.80	3.08
51-4111	Tool and Die Makers	3.42	7.60	4.90	4.56
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	2.54	4.89	4.03	3.71
51-9111	Packaging and Filling Machine Operators and Tenders	2.05	3.12	3.07	2.77
51-9198	Helpers--Production Workers	1.77	3.63	2.28	2.34
	Average of core crossovers occupations	3.36	5.90	4.05	3.61
	Average across all occupation	4.02	5.07	3.42	3.01

*Source: US BLS O*Net and 2012 OES Research Estimates by Industry and State; author's calculations.*

do engineers and engineering technicians as well as tool and die makers. Advanced manufacturing occupations have strong OJT requirements, with 15 of the twenty core/crossover occupations surpassing the occupational average—most notably architectural and engineering managers, industrial engineers, and industrial engineering technicians. Fourteen of the core occupations require above average in-plant or on-site training, essentially the same occupations requiring high levels of OJT.

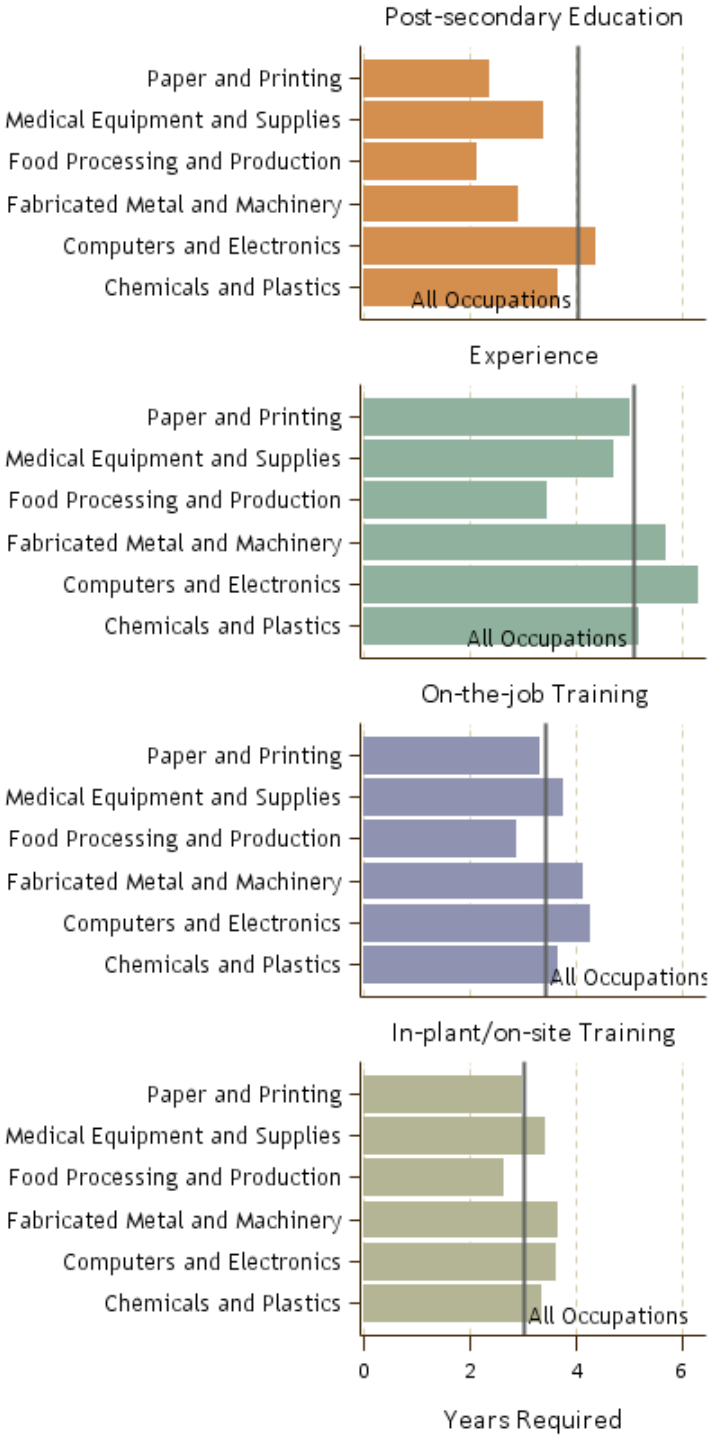
Figure 32 displays the average occupational requirements of core occupations in each subsector. Detailed occupational requirement are provided in Appendix Tables 3 to 8. On average, the core occupations in Computers and Electronics have the highest requirements across education levels and experience, as well as training. It is the only subsector where post-secondary education exceeds the average for all occupations.

The other subsectors typically expect fewer years of formal education, but require higher levels of experience and training than the state average. By contrast, requirements in Food Processing and Production are significantly lower than other subsectors. Workers in Fabricated Metals and Machinery have the second highest requirement for number of years experience and on-the-job training, on average, but somewhat lower requirements for formal education. Similar combinations of experience, training and education are required in Paper and Printing, Chemicals and Plastics, as well as Medical Equipment and Supplies.

These patterns are suggestive of how skills and knowledge are acquired in Advanced Manufacturing. Overall, we see that workers learn more from learning-by-doing experiences—although most key occupations still require at least a few years of formal post-secondary education. This further emphasizes the importance of employers and industry representative working closely with training providers, as well as continued support for OJT and apprenticeship programs.

Figure 32

Occupational requirements of subsectors, in years



*Source: US Bureau of Labor Statistics O*Net*

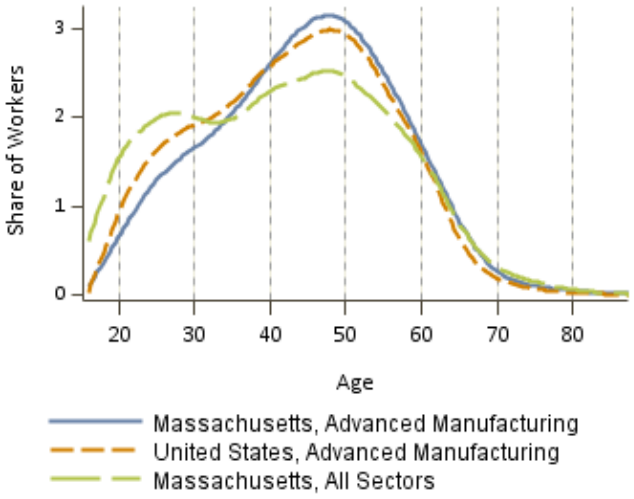
Profile of the Advanced Manufacturing Workforce

This final section examines the people that work in the Advanced Manufacturing sector: their race, sex, citizenship status, income, education, and commuting patterns. Our demographic profile heavily relies on information from the American Community Survey Public Use Microsample (ACS PUMS) — a nationally representative household survey conducted by the U.S. Census Bureau. The ACS has largely replaced the Decennial Census as the premier source of detailed information about the U.S. population, and the person-level detail in the PUMS files allow us to look specifically at the Advanced Manufacturing workforce. It is important to keep in mind that the ACS PUMS is a sample, albeit a representative one, with data pooled across multiple years (2007 to 2012) to ensure enough responses for reliable estimation. Table 14 provides a summary of the demographic characteristics of the Advanced Workforce compared to workers in all industries and across the individual subsectors.

Age

During the next twenty years we can expect a dramatic shift in composition of the Advanced Manufacturing workforce. Despite a recent history of layoffs and downsizings, in the relatively near future the Advanced Manufacturing sector may very well be facing a labor shortage. Consider Figure 33 which shows the age distribution of today's Advanced Manufacturing workers. The Massachusetts Advanced Manufacturing workforce is heavily concentrated among workers currently between 40 and 55 years old, with a median age of 45 years old. Within the next ten years, 21 percent of today's Advanced Manufacturing workforce will approach or enter the traditional retirement age of 65 years. Within the next twenty years, that portion will jump to over 50 percent. And while the greying of the manufacturing sector is a nationwide phenomenon, in Massachusetts the problem may be particularly acute with notably fewer workers in their twenties compared to the U.S.

Figure 33
Age Distribution of the Advanced Manufacturing Workforce



Source: US Census Bureau, American Community Survey Public Use Micro Sample 2008-2012, Author's Calculations

Table 14

Summary, Demographic Profile of the Massachusetts Advanced Manufacturing Workforce

	Advanced Manufacturing	Chemicals and Plastics	Computers and Electronics Products	Fabricated Metals & Machinery	Food Processing and Production	Medical Equipment and Supplies	Paper and printing	All Industries
Age								
Median	45	43	46	47	43	44	47	42
Under 25 years old	6.2	5.3	4.1	6.6	14.9	6.7	5.3	14.3
25 to 39 years	27.5	34.7	26.1	25	27.4	23.6	28.8	30.3
40 to 54 years	44.3	42.9	48.0	42.3	39.7	45.4	44.0	35.4
55 years or older	21.5	17.4	21.5	25.9	18.6	24.5	21.8	20.1
Race								
White	81.8%	79.7%	80.7%	88.1%	73.3%	79.2%	87.7%	83.7%
African American	3.4%	3.4%	2.6%	3.5%	6.6%	3.5%	2.9%	5.9%
Asian	9.4%	10.7%	13.1%	4.4%	6.6%	12.6%	3.4%	5.2%
Other	1.3%	1.3%	0.9%	1.0%	3.7%	1.1%	1.1%	1.7%
More than one race	4.1%	4.9%	2.7%	3.0%	9.8%	3.6%	4.9%	3.5%
Female	30.8%	36.4%	29.8%	19.3%	39.7%	39.1%	28.8%	48.6%
Place of Birth (percents)								
Massachusetts	50.3%	43.5%	46.5%	60.3%	45.3%	46.9%	64.5%	55.9%
New England	7.4%	7.8%	7.9%	8.0%	4.7%	7.1%	6.2%	7.0%
United States	18.7%	24.0%	20.5%	13.1%	14.4%	20.4%	15.9%	18.8%
Foreign Born	23.6%	24.7%	25.0%	18.6%	35.7%	25.6%	13.5%	18.3%
Median Income (2012 dollars)								
Family Income	$92,177	$98,083	$109,138	$80,010	$67,256	$100,570	$74,642	$82,776
Personal Income	$52,853	$60,984	$68,290	$46,088	$33,422	$58,072	$43,000	$41,152
Wage and Salary Income*	$50,820	$60,767	$66,066	$44,400	$31,340	$55,703	$40,656	$36,871
Educational Attainment								
Less than High School	8.0%	6.5%	4.8%	9.6%	21.8%	6.5%	8.3%	6.1%
High School Diploma or GED	26.2%	19.9%	18.3%	40.2%	32.9%	19.9%	39.5%	22.7%
Associates Degree or Some College	23.4%	19.6%	23.3%	25.5%	22.5%	24.5%	25.6%	25.2%
Bachelors Degree or Higher	42.5%	54.0%	53.6%	24.7%	22.8%	49.1%	26.6%	46.0%
Commuting								
Ave. Travel Time to Work (mins)	29.6	31.4	31.5	27.3	24.6	32.1	26.7	27.0
State of Primary Residence								
Massachusetts	89.7%	91.0%	88.9%	91.4%	92.9%	89.6%	92.2%	94.3%
Connecticut	0.8%	0.7%	0.7%	1.3%	0.2%	0.7%	1.5%	0.6%
New Hampshire	5.5%	5.1%	7.2%	4.1%	2.9%	6.5%	4.7%	2.5%
New York	0.2%	0.2%	0.2%	0.2%	0.0%	0.1%	0.1%	0.2%
Rhode Island	2.9%	2.9%	3.0%	2.8%	3.9%	3.0%	1.5%	1.7%
Vermont	0.1%	0.2%	0.1%	0.1%	0.0%	0.0%	0.0%	0.1%
Other	0.9%	1.7%	1.0%	0.8%	0.4%	0.8%	0.4%	0.6%

*Note: Wage and Salary Income reported in the ACS is different than the Total Wage and Salary reported from the Bureau of Labor Statistics and State Affliates. The ACS is based on a much smaller sample of the workforce and does not include the dollar value of benefits as reported in BLS employer surveys.

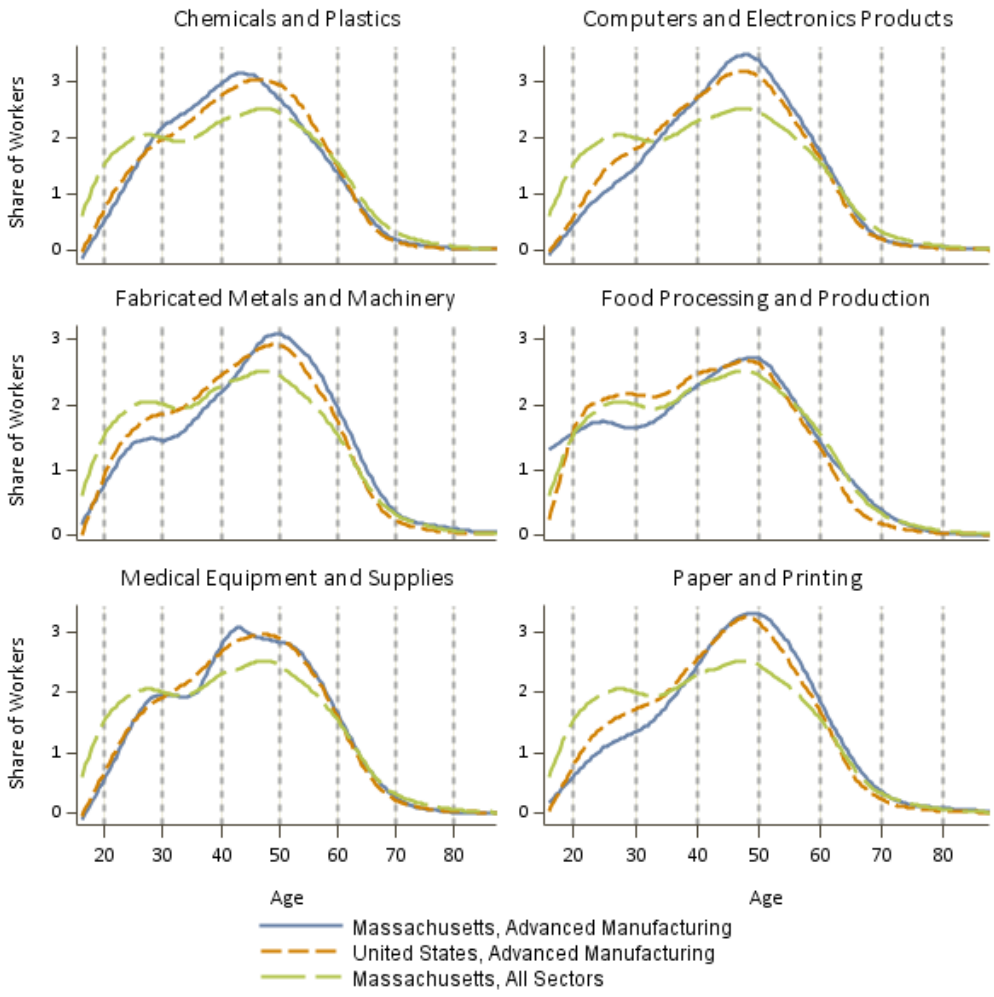
Source: US Census Bureau, American Community Survey Public Use Micro Sample 2008-2012, Author's Calculations

There is both good and bad in this news. Under a worse case scenario, a substantial number of producers leave Massachusetts due to their inability to find appropriately skilled workers. As a nationwide crisis, Massachusetts may not be at as much a locational disadvantage relative to other states, although it may pose a competitive disadvantage on the global scale. Local producers might be more tempted to replace labor with labor-saving capital equipment to make up for the shortfall. Furthermore, the retirement of older workers is not simply a numerical issue of replacement, but also represents the loss of a considerable wealth of experience and knowledge learned on the job.

On the plus side, the wave of retirements in the coming decades could translate into opportunities for younger workers seeking well-paying jobs in the state's manufacturing sector. That is assuming that they are appropriately trained and aware of manufacturing as a viable career path. As such, employers and industry representative have begun partnering with workforce and education officials to establish new training and apprenticeship programs as well as outreach programs targeting area students and schools.

The age distributions for the six subsectors generally match that of the Advanced Manufacturing sector as a whole (Figure 34). While there are some differences between industries, all

Figure 34
Age Distribution of the Advanced Manufacturing Workforce by subsector



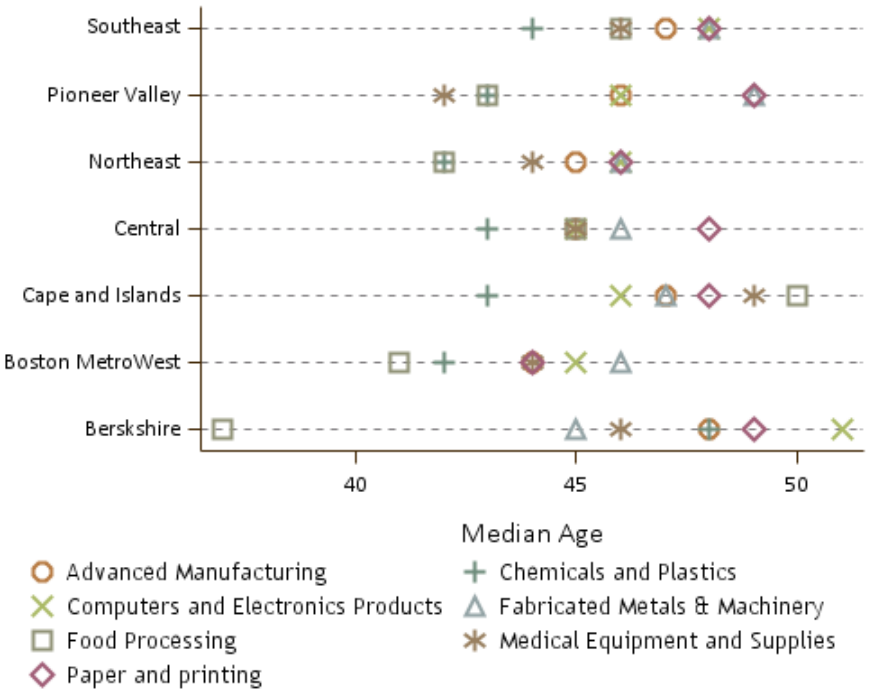
Source: US Census Bureau, American Community Survey Public Use Micro Sample 2008-2012, Author's Calculations

will be facing an unprecedented wave of retirements in the coming decades if current trends continued. Fabricated Metals and Machinery is the oldest subsector, with a median age of 47 years and over 57 percent of workforce expected to reach standard retirement age in the next twenty years. However, we see some evidence of recent success in recruiting twenty-year olds into the industry — although less than the trend among national producers. Despite its high-tech image, Computers and Electronics also has a large share of impending retirements, but unlike Fabricated Metals it has few relatively young workers coming up behind.

The 'youngest' subsector is Food Processing and Production where the typical worker is currently in his/her early forties. The age distribution for Food Processing and Production is a bit 'flatter'—meaning that there are more relatively younger workers in the pipeline. This may mute the negative acute impacts from anticipated retirements. Chemicals and Plastics also skews a bit younger, where the typical worker is also in his/her early forties and there appears to be a secondary peak of workers in their early thirties.

The age of the workforce also varies by region, although much of this is due to regional difference in industry mix (Figure 35). Despite some exceptions, generally we see more variation in age across subsectors than across regions—the Food Processing and Chemicals and Plastics tend to be among the "younger" subsectors in most regions, while Paper and Printing and Fabricated Metals tend to be among the older.

Figure 35
Median Age by Region and Subsector



Source: US Census Bureau, American Community Survey Public Use Micro Sample 2008-2012, Author's Calculations

Race, Gender and Nativity

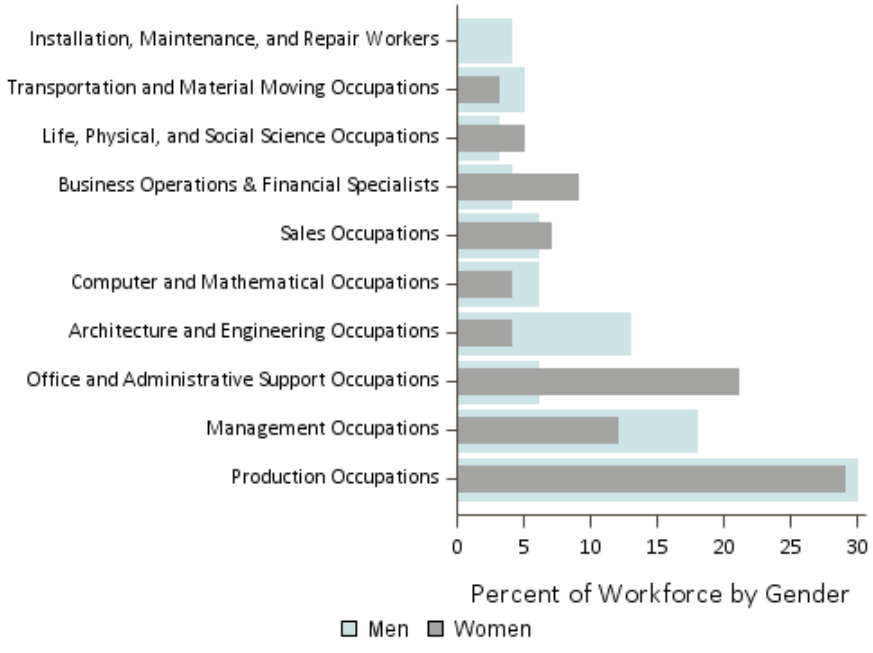
The workforce of Advanced Manufacturing is predominantly white, but at a level that nearly matches the overall workforce in the Commonwealth (Table 14). Asians are particularly well represented relative to their size in

the overall workforce, while African Americans are underrepresented. The degree of racial diversity in Advanced Manufacturing varies by subsector. Food Processing is the most diverse, with nearly 27 percent of the workforce made up by non-whites. This subsector also exceeds the state average in all racial categories. Fabricated Metals is the least diverse, with racial minorities comprising less than twelve percent of the overall workforce.

Although predominantly white, Advanced Manufacturing has a higher than average share of its workforce comprised of foreign born workers—24% compare to the all industry average of 18%. Four of the six subsectors have a higher share of foreign born workers than the Commonwealth average. Food Processing has the highest share of foreign born workers (36%). Paper and Printing, the least (13.6%). Among those born in the U.S., roughly half of those currently working in Advanced Manufacturing are Massachusetts natives—particularly in Paper and Printing and Fabricated Metals where over 60% of workers were born in the Commonwealth.

Advanced Manufacturing is also predominantly male. Women make up only 31% of the current workforce, compared to nearly half of the state's overall labor force. While women are underrepresented in every subsector, the gender divide is largest is Fabricated Metals and Paper and Printing and smallest in Food Processing and Medical Equipment and Supplies. The gender gap in manufacturing is recognized as a longstanding problem, although there are ongoing initiatives promoting manufacturing to young women as a viable career path. These include the Manufacturing Institute's STEP program, the Women in Manufacturing (WIM) initiative, and Federal Department of Labor technical assistance grants to support training for women pursing non-traditional occupations.

Figure 36
Gender Differences by Major Occupation Groups in Advanced Manufacturing



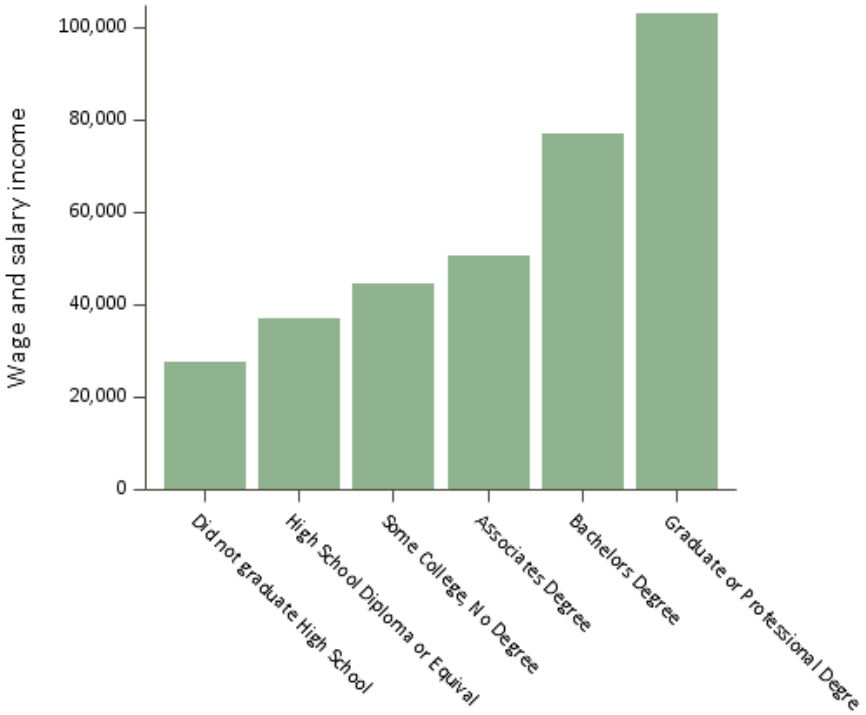
Source: US Census Bureau, American Community Survey Public Use Micro Sample 2008-2012, Author's Calculations

There is also a divide in the types of occupations staffed by women relative to men (Figure 36). The largest share of women working in Advanced Manufacturing are in production occupations (29%)—a share commensurate with men. However, women are heavily specialized in administrative and office support occupations—21% of women compared to only 6% of men. This is closely followed by business operations, where there is a 5 percentage point gender imbalance. By contrast, men are far more prominent in the typically more lucrative management and architecture and engineering occupations.

Educational Attainment and Income

It is often said that manufacturing is one of the few remaining sectors where someone without a college degree can earn a good wage. But while college may not be a pre-requisite for a living wage, the majority of people working in manufacturing today have at least some college education and those with higher degrees earn considerably more than those without (Figure 37). Only eight percent of the Advanced Manufacturing workforce lack a high school diploma, just slightly more than the Massachusetts average of six percent (Table 14). Yet this share is heavily skewed by the Food Processing and Production subsector where those lacking degrees make up 21% of the workforce. Food processing also hires a notably larger percentage of minorities, women, and foreign born—and pays considerably less than the other Advanced Manufacturing subsectors. Fabricated Metals and Machinery also hire a disproportionate share of workers without high school diplomas. But in contrast to Food Processing and Production, Fabricated Metals has the lowest shares of foreign born, minority and female workers. A majority of the

Figure 37
Median Wage and Salary Earnings by Education, Advanced Manufacturing



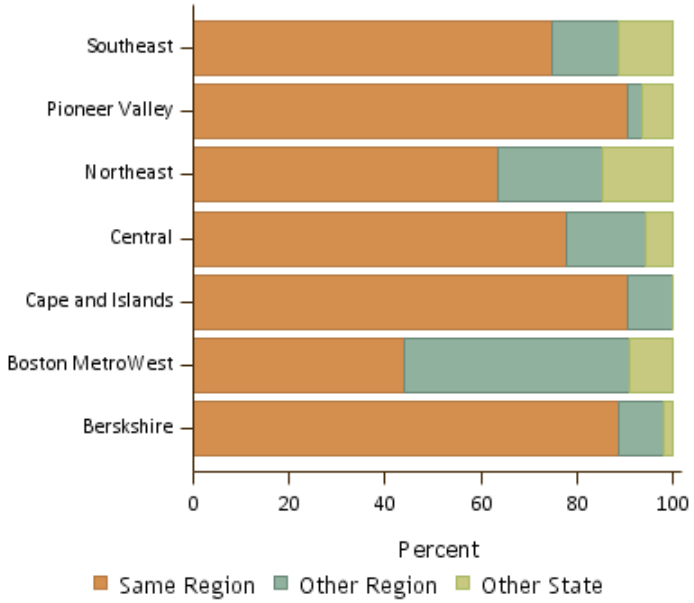
Source: US Census Bureau, American Community Survey Public Use Micro Sample 2008-2012, Author's Calculations

workers in Chemicals and Plastics and in Computers and Electronics have a Bachelors and Graduate degree.

Residency and Commuting Patterns

The vast of workers in the Advanced Manufacturing sector both live and work in Massachusetts (Table 14). Their average commute length is 30 minutes, just under three minutes more than the state average, and with a slightly higher share commuting in from out of state. Among those living outside Massachusetts, most come from New Hampshire or Rhode Island. There are only slight differences in-state residency shares across the six study sectors, but these differences have more to do with regional industrial specializations and the proximity of major employment centers to state boundaries than industry-specific difference, per se.

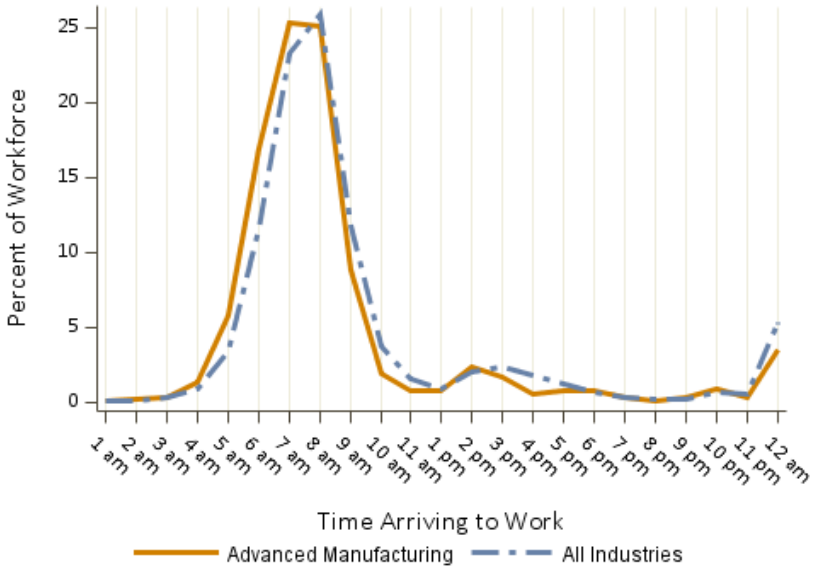
Figure 38
Place of Residence by Region



Source: US Census Bureau, American Community Survey Public Use Micro Sample 2008-2012, author's calculations

Among the seven study regions, the Northeast has the highest share commuting in from out-of-state, followed by the Southeast and Boston MetroWest regions. The Cape and Island have very few out of state commuters followed by the Berkshires—despite its proximity to Albany, New York. Boston MetroWest has, by far, the greatest share of commuters coming in from other regions within Massachu-

Figure 39
Time Arriving to Work

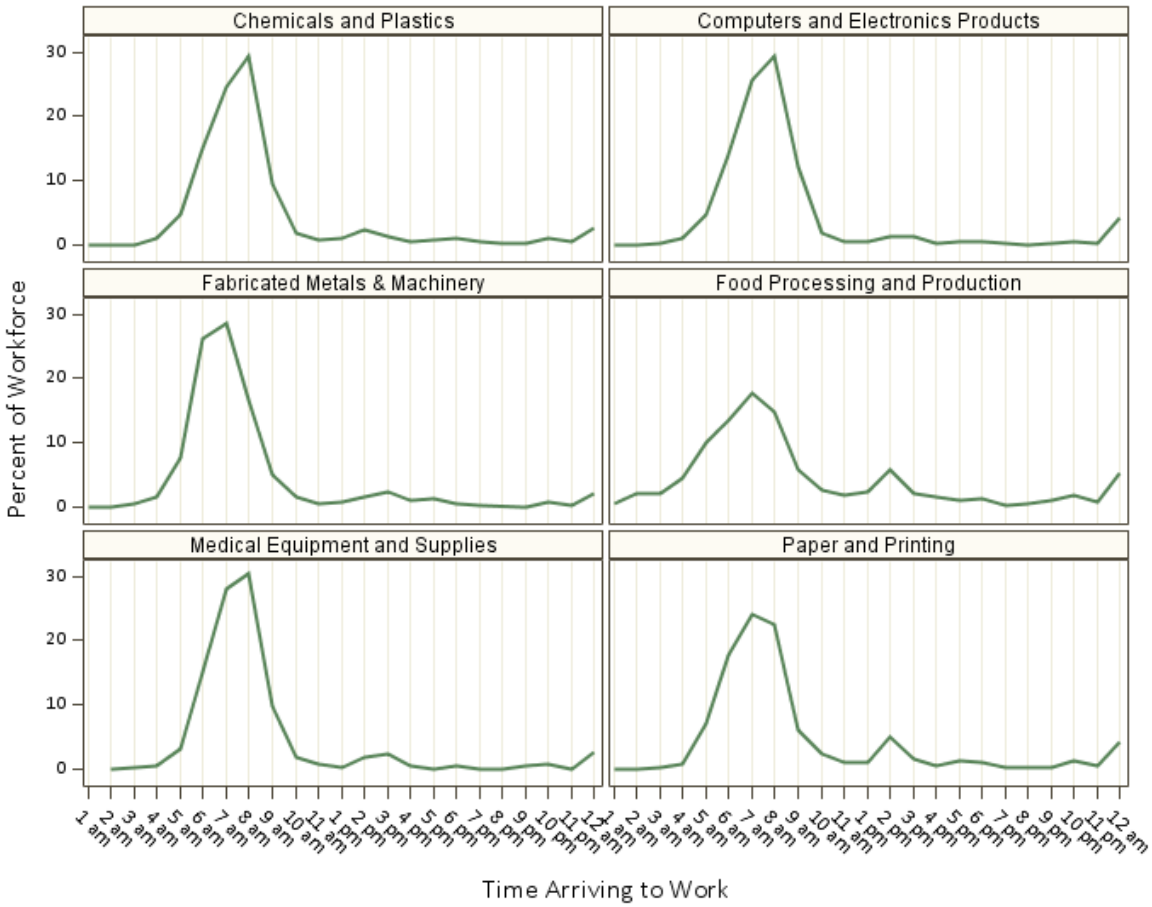


Source: US Census Bureau, American Community Survey Public Use Micro Sample 2008-2012, author's calculations

setts, reflecting its status as a regional employment hub. The Pioneer Valley has the lowest share of workers commuting in from other areas of Massachusetts, likely due to its physical separation by the Quabbin Reservoir (to the east) and Berkshire Mountains (to the west).

The typical worker in Advanced Manufacturing enjoys a relative standard work day, although starting a bit earlier than workers in other sectors (Figure 39). The mass of workers arrive to work between 6:00 and 8:00 am, whereas for most other industries the typical peak is between 7:00 and 9:00 am. We also see lesser peaks around 2:00 pm and midnight—evidence of second and third shifts. The basic same pattern holds for the subsectors (Figure 40). Chemicals and Plastics and Computers and Electronic Products show a typical single-shift, 8:00 am arrival time. Start time for Food Processing and Production and Paper and Printing are more spread throughout the workday with secondary peaks representing multiple work shifts.

Figure 40
Time Arriving to Work, by Advanced Manufacturing Subsector



Source: US Census Bureau, American Community Survey Public Use Micro Sample 2008-2012, author's calculations

Appendix Table 1

Occupational Information Network (O*Net) skill definitions

Skill name or category	Description
Content	*Background structures needed to work with and acquire more specific skills in a variety of different domains*
Reading Comprehension	Understanding written sentences and paragraphs in work related documents.
Active Listening	Giving full attention to what other people are saying, taking time to understand the points being made, asking questions as appropriate, and not interrupting at inappropriate times.
Writing	Communicating effectively in writing as appropriate for the needs of the audience.
Speaking	Talking to others to convey information effectively.
Mathematics	Using mathematics to solve problems.
Science	Using scientific rules and methods to solve problems.
Process	*Procedures that contribute to the more rapid acquisition of knowledge and skill across a variety of domains*
Critical Thinking	Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems.
Active Learning	Understanding the implications of new information for both current and future problem-solving and decision-making.
Learning Strategies	Selecting and using training/instructional methods and procedures appropriate for the situation when learning or teaching new things.
Monitoring	Monitoring/Assessing performance of yourself, other individuals, or organizations to make improvements or take corrective action.
Social Skills	*Developed capacities used to work with people to achieve goals*
Social Perceptiveness	Being aware of others' reactions and understanding why they react as they do.
Coordination	Adjusting actions in relation to others' actions.
Persuasion	Persuading others to change their minds or behavior.
Negotiation	Bringing others together and trying to reconcile differences.
Instructing	Teaching others how to do something.
Service Orientation	Actively looking for ways to help people.
Complex Problem Solving Skills	*Developed capacities used to solve novel, ill-defined problems in complex, real-world settings*
Complex Problem Solving	Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.
Technical Skills	*Developed capacities used to design, set-up, operate, and correct malfunctions involving application of machines or technological systems*
Operations Analysis	Analyzing needs and product requirements to create a design.
Technology Design	Generating or adapting equipment and technology to serve user needs.
Equipment Selection	Determining the kind of tools and equipment needed to do a job.
Installation	Installing equipment, machines, wiring, or programs to meet specifications.
Programming	Writing computer programs for various purposes.
Operation Monitoring	Watching gauges, dials, or other indicators to make sure a machine is working properly.
Operation and Control	Controlling operations of equipment or systems.
Equipment Maintenance	Performing routine maintenance on equipment and determining when and what kind of maintenance is needed.
Troubleshooting	Determining causes of operating errors and deciding what to do about it.
Repairing	Repairing machines or systems using the needed tools.
Quality Control Analysis	Conducting tests and inspections of products, services, or processes to evaluate quality or performance.

Appendix Table 1 (continued)

Occupational Information Network (O*Net) skill definitions

Skill name or category	Description
Systems Skills	*Developed capacities used to understand, monitor, and improve socio-technical systems*
Judgment and Decision Making	Considering the relative costs and benefits of potential actions to choose the most appropriate one.
Systems Analysis	Determining how a system should work and how changes in conditions, operations, and the environment will affect outcomes.
Systems Evaluation	Identifying measures or indicators of system performance and the actions needed to improve or correct performance, relative to the goals of the system.
Resource Management Skills	Developed capacities used to allocate resources efficiently
Time Management	Managing one's own time and the time of others.
Management of Financial Resources	Determining how money will be spent to get the work done, and accounting for these expenditures.
Management of Material Resources	Obtaining and seeing to the appropriate use of equipment, facilities, and materials needed to do certain work.
Management of Personnel Resources	Motivating, developing, and directing people as they work, identifying the best people for the job.

Appendix Table 2

Skill requirements of Massachusetts' Core/Crossover Occupations

SOC code	Core occupation	Number	Mean annual wage	Level or Importance	Reading Comprehension	Active Listening	Writing	Speaking	Mathematics	Science	Critical Thinking	Active Learning	Learning Strategies	Monitoring	Social Perceptiveness	Coordination	Persuasion	Negotiation	Instructing	Service Orientation
51-1011	First-Line Supervisors of Production and Operating Workers	6,230	$65,401	LV	3.62	3.75	3.75	3.88	2.5	0.88	3.88	3.25	3.25	3.5	3.75	3.88	3.12	3.12	3.25	2.88
				IM	3.88	4	3.25	4	2.12	1.75	3.88	3.12	3.12	3.62	3.5	3.88	3.25	3.12	3.12	2.88
51-4041	Machinists	6,050	$45,943	LV	3	2.88	2.75	3	2.62	0.88	3.12	2.88	2.62	3.25	2.75	3	2.5	2.12	2.88	2.38
				IM	3	3	2.75	2.88	2.62	1.5	3.12	2.75	2.38	3	2.75	3	2.5	2.5	2.62	2.12
51-2092	Team Assemblers	5,290	$33,053	LV	2.62	2.88	2.88	3	1.38	0	3	2.12	2.38	3	2.5	3.38	2.25	1.62	2.62	1.88
				IM	2.88	3	2.5	3	2	1	3	2.38	2.25	3.12	2.75	3.12	2.38	1.88	2.5	2
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	4,080	$40,316	LV	3.12	3.12	2.88	2.88	2.5	1.25	3.38	2.25	1.88	3.12	2.25	2.88	2.12	1.5	1.88	1.75
				IM	3.12	3.38	2.88	3.12	2.5	1.75	3.12	2.38	2	3.12	2.75	3	2.25	1.88	2	1.88
17-2141	Mechanical Engineers	3,230	$89,290	LV	5.12	4.12	4.12	3.88	5.12	4.62	4.38	4.62	3.62	4.5	3.12	3.88	3.5	3	3.62	3
				IM	3.75	3.75	3.38	3.38	3.75	3.62	3.88	3.38	2.75	3.12	2.75	3	2.88	2.62	2.75	2.62
17-3023	Electrical and Electronics Engineering Technicians	3,210	$57,116	LV	3.62	3.25	3.38	3.25	3	2.62	3.38	2.75	2.38	3.25	2.75	3.25	2.5	2.38	2.75	2.5
				IM	3.5	3.25	3.12	3.25	2.75	2.5	3.25	2.75	2.38	3	2.88	3.12	2.5	2.38	2.62	2.5
17-2112	Industrial Engineers	3,010	$87,456	LV	4.5	3.75	4	3.62	3.62	1.62	4.12	3.62	3.12	4.12	2.88	3.38	3.12	2.75	3.38	2.88
				IM	4	3.75	3.75	3.62	3.25	1.88	3.75	3.25	2.88	3.5	3.12	3.25	2.88	2.75	3.12	2.75
51-9111	Packaging and Filling Machine Operators and Tenders	2,820	$28,003	LV	2.88	2.5	2.38	2.38	2	0	2.38	2.25	2.12	2.75	2.5	2.88	2.12	2.12	2.38	2.12
				IM	3	3.12	2.5	2.88	2.12	1	2.88	2.38	2.38	3.25	2.88	3.12	2.25	2.25	2.62	2.38
51-9198	Helpers--Production Workers	2,660	$26,986	LV	2.25	2.38	1.62	2.25	1.62	0.5	2.38	1.88	1.5	2.38	2.38	2.12	1.12	1.25	1.62	1.38
				IM	2.75	2.88	2	2.75	2.12	1.25	2.88	2	2	2.75	2.75	2.25	1.88	1.88	2	1.75
11-3051	Industrial Production Managers	2,350	$107,135	LV	4	4	3.75	3.88	3.38	1.12	4.12	4	3.75	5	3.62	4.5	3.88	3.88	3.62	3.25
				IM	3.5	3.75	3.12	3.75	3.12	1.62	4	3.62	3.5	4	3.25	4	3.38	3.38	3.38	2.88
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	2,250	$45,141	LV	3.5	3.38	2.5	3.12	3.25	1.25	3.75	3.38	3.25	3.75	2.62	2.88	2.5	2	3.12	2.12
				IM	3.38	3.25	2.62	3	2.88	1.75	3.62	2.88	2.62	4	3	2.88	2.12	2	2.62	2.12
11-9041	Architectural and Engineering Managers	2,240	$151,556	LV	4.38	4.12	4.12	4.12	3.75	2.38	4.25	4.25	3.38	4.12	3.75	4.12	3.88	4	3.5	3.38
				IM	4.12	3.88	3.62	3.75	3.62	2.38	4	3.5	3.12	3.62	3.5	3.75	3.38	3.38	3.25	3
51-2023	Electromechanical Equipment Assemblers	1,980	$39,255	LV	3	2.75	2.38	2.62	1.75	2	3	2.12	1.75	2.62	2.12	2.62	2	2	2.38	1.75
				IM	3.12	2.75	2.5	2.88	2.12	2.12	3	2.38	2.12	2.75	2.5	2.62	2.12	2.12	2.38	2.25
51-4072	Molding, Coremaking, and Casting Machine Setters, Operators, and Tenders, Metal and Plastic	1,930	$31,209	LV	2.38	2.5	2.25	2.25	2.12	0.25	2.5	2.25	1.88	2.88	2	2	1.62	1.5	1.75	1.38
				IM	3	3.12	2.62	2.88	2.12	1.25	3	2.62	2.12	3	2.62	2.25	2.12	2.12	2	1.88
51-4081	Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic	1,610	$35,933	LV	2.62	2.88	2.62	3	1.88	0.5	3.12	2.75	2.62	3	2.38	2.88	2.25	2	3.12	2.25
				IM	3	3.12	2.62	3	2.25	1.25	3.25	2.5	2.38	3.38	2.88	2.88	2.38	2.12	3.12	2.5
49-9041	Industrial Machinery Mechanics	1,520	$54,073	LV	3.5	2.88	2.62	2.88	2.5	1.62	3.5	3	3.12	3.12	2.38	2.75	2.38	1.75	3	2.38
				IM	3	3.25	2.88	2.88	2.38	2	3.5	3	2.75	3.5	2.88	2.62	2.38	2.12	2.88	2.38
17-3026	Industrial Engineering Technicians	1,080	$54,729	LV	4	3.62	3.62	3.75	4	2.88	3.75	3.88	2.75	4.38	3.25	3.5	3.5	2.88	2.88	2.88
				IM	3.75	3.62	3.25	3.38	3.12	3	3.75	3	2.5	3.75	3	2.88	2.88	2.75	2.75	2.75
51-4031	Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic	1,000	$35,973	LV	3.38	2.75	2.75	2.88	2.12	0.62	2.62	2.5	1.88	2.62	2.25	2.75	2.5	2.5	2.12	1.75
				IM	3.12	3.25	2.5	3	2.38	1.38	3	2.5	2.25	3.12	2.75	2.62	2.25	2.12	2.25	2
51-4021	Extruding and Drawing Machine Setters, Operators, and Tenders, Metal and Plastic	870	$40,178	LV	2.62	2.62	2.38	2.62	2.25	1.25	2.5	2.38	2.12	3.12	2.38	2.75	2.25	1.88	2.25	2.12
				IM	3	2.88	2.5	2.88	2.5	1.75	3.12	2.75	2.25	3.5	3	3	2.62	2.12	2.25	2.5
51-4111	Tool and Die Makers	860	$49,018	LV	3	3	2.5	2.5	2.5	1.5	3	3	2.38	3	2	2.88	1.62	1.38	2.25	1.38
				IM	2.88	3	2.38	2.88	2.62	1.88	3.12	2.88	2.12	2.88	2.62	2.88	2	1.75	2.12	1.75

Appendix Table 2 (continued)

Skill requirements of Massachusetts' Core/Crossover Occupations

SOC code	Core occupation	Complex Problem Solving	Operations Analysis	Technology Design	Equipment Selection	Installation	Programming	Operation Monitoring	Operation and Control	Equipment Maintenance	Troubleshooting	Repairing	Quality Control Analysis	Judgment & Decision Making	Systems Analysis	Systems Evaluation	Time Management	Mgmt of Financial Resources	Mgmt of Material Resources	Mgmt of Personnel Resources
51-1011	First-Line Supervisors of Production and Operating Workers	3.5	3	1.12	2.12	0.38	0.25	3.25	2.62	2.25	2.5	2.38	3.12	3.25	3.12	3	3.88	2.75	2.62	3.88
		3.25	3	1.88	2.25	1.25	1.12	3.12	2.5	2.25	2.38	2.25	3.12	3.75	2.88	3	3.88	2.38	2.38	3.88
51-4041	Machinists	3	2	2.25	2.62	2.25	1.12	3.38	3.25	2.75	2.75	2.62	3	2.75	2.25	2.25	2.75	0.38	1	2.25
		2.88	2.12	2.25	2.88	2.5	1.62	3.25	3.12	2.62	2.75	2.62	2.88	2.88	2.5	2.62	2.88	1.38	1.62	2
51-2092	Team Assemblers	2.5	0.5	0.25	1.12	0	0.5	2.88	2.88	2	2	1.5	2.75	2.62	1.88	1.75	2.5	0.62	0.75	2.38
		2.75	1.38	1.25	1.75	1	1.5	2.88	2.62	2.12	2	1.88	3.12	2.75	2	2	3	1.5	1.75	2.88
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	2.62	1.25	0.38	0.62	0.5	0.5	3.12	2.5	0.75	1.75	0.75	3.12	2.88	2	2.25	2.62	0.62	0.75	1.88
		2.75	1.88	1.38	1.5	1.25	1.5	3	2.62	1.38	1.88	1.38	3.5	3	2.12	2.38	2.75	1.62	1.75	2
17-2141	Mechanical Engineers	4.5	4.5	4	3.12	3	3.12	3.88	2.25	2.12	3.62	1.75	4.25	4.62	4.12	4.25	3.5	2.62	3.12	3.5
		4	3.5	3.25	2.25	2.25	2.62	3.12	2.12	2	3	1.75	3.12	3.75	3.38	3.38	3.12	2.25	2.5	2.88
17-3023	Electrical and Electronics Engineering Technicians	3.38	3.12	1	2.62	0.5	1.62	3	2.62	3.12	3.38	3.25	3	2.88	2.88	2.88	3.12	0.75	1.25	2.5
		3.5	3.12	1.62	2.5	1.25	2	3	2.62	2.75	3	2.88	2.75	2.88	2.75	2.75	3.38	1.62	1.75	2.5
17-2112	Industrial Engineers	4	2	1.75	0.5	0	1.5	2.88	2	0	1.75	0	2.25	3.62	3.62	3.62	3.38	2.5	2.88	3
		3.75	2.12	2.12	1.25	1	1.75	2.38	2.12	1	2	1	2.12	3.38	3.12	3	3.25	2.38	2.62	3
51-9111	Packaging and Filling Machine Operators and Tenders	2.38	0	0.25	1.88	0	0	3.5	3	2.62	2.62	2.38	2.5	2.38	1.75	1.88	2.38	0.25	0.38	1.88
		2.75	1	1.12	2.12	1	1	3.25	3	2.5	2.5	2.38	3.12	2.88	2.25	2.12	2.88	1.25	1.38	2.12
51-9198	Helpers--Production Workers	2	1.12	0.62	1.12	0.12	0	2.38	2.12	1.25	1.75	1.38	2	1.88	1	1	1.75	0.38	0.62	1.62
		2.38	1.62	1.5	1.88	1.12	1	2.38	2.38	2	2	2	2.25	2.38	1.88	1.88	2.5	1.5	1.5	2.12
11-3051	Industrial Production Managers	3.88	2.88	1.62	1.38	0	1.5	3.88	3.12	0.5	1.88	0.5	3.5	4.62	4.12	3.88	4.38	4	3.75	4.62
		3.5	2.88	1.88	1.75	1	1.75	2.88	2.62	1.38	2.12	1.38	3.25	3.5	3.38	3.25	3.88	3.25	3.25	3.88
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	3.12	2.25	1.75	2.62	1.5	2.5	4	3.62	2.88	3.25	2.75	3.75	3.12	2.88	2.75	2.88	1	1.5	2.25
		3.38	2.62	1.88	3.12	2	2.88	3.88	3.5	3	3.12	2.88	3.62	3.38	2.62	2.75	3.12	1.75	2.12	2.62
11-9041	Architectural and Engineering Managers	4.12	1.88	1.62	0.5	0.5	1.38	2.62	1.5	0	1.88	0.5	3.12	4.25	3.5	3.25	4	3.38	3.25	4
		3.75	2.25	1.88	1.25	1.12	2	2.5	1.88	1	1.88	1.12	2.88	3.75	3.25	3.25	3.75	3	3	3.12
51-2023	Electromechanical Equipment Assemblers	2.12	0.62	0.88	1.75	0.5	0.5	3	2.12	2.88	3.25	2.5	3.38	2.62	1.5	1.25	2.62	0.38	0.75	1.88
		2.38	1.5	1.75	2.12	1.38	1.38	3.12	2.5	2.62	3	2.62	3.25	2.75	2	1.88	2.75	1.38	1.62	2.25
51-4072	Molding, Coremaking, and Casting Machine Setters, Operators, and Tenders, Metal and Plastic	2.38	1.75	1	2	1.12	0	3.75	3.62	2.62	2.75	2.5	3.38	2.25	0.12	1.62	2.38	0	0.38	1.62
		2.62	2.12	1.62	2.25	1.75	1	3.5	3.5	2.88	2.88	2.75	3.25	2.5	1.12	2.25	2.75	1	1.38	1.88
51-4081	Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic	2.88	1.88	0.88	2.25	1.5	0.25	3.5	3.25	3.25	3.12	3	3.25	2.62	2.12	2.12	2.62	0.38	1.12	2.38
		3.25	2.25	1.5	2.5	2.12	1.25	3.75	3.25	3	3.12	2.88	3.5	2.88	2.25	2.38	3	1.25	1.62	2.38
49-9041	Industrial Machinery Mechanics	3.12	2	2	3	2.62	1.75	4.25	3.5	4.25	4	4.25	3.62	3.12	2.88	2.88	2.88	1.12	1.25	2.38
		3.25	2.12	2.38	3.5	2.5	2.12	4	3.75	4.12	4	4.38	3.88	3.38	2.75	2.75	3	1.88	1.88	2.62
17-3026	Industrial Engineering Technicians	3.88	3.25	3.38	0.88	0	2	3.12	2.12	0.25	2.12	0	3.12	3.88	3.88	4	3	1	1.38	2.88
		3.75	3.12	3	1.5	1	2	3	2.12	1.12	2.12	1	2.62	3.25	3.5	3.38	3.12	1.75	2	2.5
51-4031	Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic	2.75	1.88	0.5	1.38	1.12	0	3.38	3.38	2.88	2.5	2.5	3.38	2.75	1.12	1.12	2.62	0.25	1	1.62
		2.75	1.88	1.38	2.12	1.75	1	3.38	3.25	2.5	2.5	2.25	3.25	2.62	1.75	1.75	2.75	1.25	1.62	2
51-4021	Extruding and Drawing Machine Setters, Operators, and Tenders, Metal and Plastic	2.75	1.88	0.75	2.62	1.88	0	3.62	3.38	2.62	2.62	2.75	3.38	2.88	1.75	1.75	2.5	0.62	1.62	2.12
		3.12	2.25	1.5	2.75	2.38	1	3.75	3.38	2.88	3	2.88	3.38	3.12	2.12	2.5	2.75	1.62	2.12	2.38
51-4111	Tool and Die Makers	3	3	2.88	3	0.75	0.75	3.25	3.12	2.88	3	2.88	3.5	3	2.38	2.25	3	0.38	0.5	1.62
		2.88	2.88	2.62	3	1.62	1.62	3.12	3.38	2.88	2.62	2.5	3.12	3	2.75	2.38	2.88	1.38	1.5	1.88

Appendix Table 3

Skill requirements of Chemicals and Plastics Core Occupations

SOC	Occupation description	Education	Experience	On-the-job training	In-plant or on-site training
51-4072	Molding, Coremaking, and Casting Machine Setters, Operators, and Tenders, Metal and Plastic	1.94	2.90	2.48	2.28
51-1011	First-Line Supervisors of Production and Operating Workers	3.47	8.61	4.65	3.84
51-9023	Mixing and Blending Machine Setters, Operators, and Tenders	2.36	3.77	3.31	3.13
51-9111	Packaging and Filling Machine Operators and Tenders	2.05	3.12	3.07	2.77
11-3051	Industrial Production Managers	3.90	7.50	4.78	4.73
51-4021	Extruding and Drawing Machine Setters, Operators, and Tenders, Metal and Plastic	2.10	3.46	3.43	3.04
19-2031	Chemists	6.71	6.55	3.83	3.64
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	2.54	4.89	4.03	3.71
19-4031	Chemical Technicians	4.76	4.83	3.51	3.53
49-9041	Industrial Machinery Mechanics	2.81	6.60	4.95	4.65
19-4021	Biological Technicians	5.99	5.39	3.42	2.99
51-9011	Chemical Equipment Operators and Tenders	2.23	4.65	3.45	3.15
19-1021	Biochemists and Biophysicists	10.18	6.86	3.50	2.73
17-2112	Industrial Engineers	5.44	7.45	5.17	4.93
51-9198	Helpers--Production Workers	1.77	3.63	2.28	2.34
19-1022	Microbiologists	8.77	5.86	3.96	3.59
	Average of core crossovers occupations	3.62	5.16	3.63	3.32
	Average across all occupation	4.02	5.07	3.42	3.01

*Source: US BLS O*Net and 2012 OES Research Estimates by Industry and State; author's calculations.*

Appendix Table 4

Skill requirements of Computers and Electronics Products Core Occupations

SOC	Occupation description	Education	Experience	On-the-job training	In-plant or on-site training
51-2022	Electrical and Electronic Equipment Assemblers	2.32	2.87	3.65	2.20
17-3023	Electrical and Electronics Engineering Technicians	4.64	8.13	4.52	4.12
17-2071	Electrical Engineers	6.23	7.55	5.47	4.85
17-2141	Mechanical Engineers	6.52	7.94	4.07	3.42
17-2112	Industrial Engineers	5.44	7.45	5.17	4.93
15-1133	Software Developers, Systems Software	5.68	7.40	3.80	3.46
11-9041	Architectural and Engineering Managers	6.71	9.62	5.20	4.64
51-2023	Electromechanical Equipment Assemblers	3.09	4.13	3.58	3.50
51-2092	Team Assemblers	2.07	2.99	2.76	2.75
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	2.54	4.89	4.03	3.71
17-2072	Electronics Engineers, Except Computer	6.16	8.30	4.49	4.27
51-1011	First-Line Supervisors of Production and Operating Workers	3.47	8.61	4.65	3.84
15-1132	Software Developers, Applications	6.32	7.40	3.94	2.80
51-9141	Semiconductor Processors	2.00	3.30	4.11	3.54
17-2061	Computer Hardware Engineers	6.00	8.93	3.98	3.33
17-3026	Industrial Engineering Technicians	4.63	6.37	5.04	4.10
51-4041	Machinists	2.94	6.12	4.65	4.14
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	2.28	4.64	3.60	2.43
	Average of core crossovers occupations	4.34	6.27	4.24	3.59
	Average across all occupation	4.02	5.07	3.42	3.01

*Source: US BLS O*Net and 2012 OES Research Estimates by Industry and State; author's calculations.*

Appendix Table 5

Skill requirements of Fabricated Metals and Machinery Core Occupations

SOC	Occupation description	Education	Experience	On-the-job training	In-plant or on-site training
51-4041	Machinists	2.94	6.12	4.65	4.14
51-1011	First-Line Supervisors of Production and Operating Workers	3.47	8.61	4.65	3.84
51-2092	Team Assemblers	2.07	2.99	2.76	2.75
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	2.54	4.89	4.03	3.71
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	2.28	4.64	3.60	2.43
51-4081	Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic	2.19	5.05	4.80	3.08
17-2141	Mechanical Engineers	6.52	7.94	4.07	3.42
51-4121	Welders, Cutters, Solderers, and Brazers	2.62	6.92	4.70	4.84
51-2041	Structural Metal Fabricators and Fitters	2.07	4.51	3.09	3.33
51-4193	Plating and Coating Machine Setters, Operators, and Tenders, Metal and Plastic	1.76	2.11	3.73	2.72
51-4033	Grinding, Lapping, Polishing, and Buffing Machine Tool Setters, Operators, and Tenders, Metal and Plastic	2.07	2.85	3.22	2.56
17-2112	Industrial Engineers	5.44	7.45	5.17	4.93
51-4031	Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic	1.85	3.08	3.08	2.89
51-9198	Helpers--Production Workers	1.77	3.63	2.28	2.34
51-4034	Lathe and Turning Machine Tool Setters, Operators, and Tenders, Metal and Plastic	2.47	6.30	4.03	3.27
11-3051	Industrial Production Managers	3.90	7.50	4.78	4.73
49-9041	Industrial Machinery Mechanics	2.81	6.60	4.95	4.65
51-4111	Tool and Die Makers	3.42	7.60	4.90	4.56
51-9121	Coating, Painting, and Spraying Machine Setters, Operators, and Tenders	1.82	5.07	3.33	3.50
	Average of core crossovers occupations	2.88	5.64	4.11	3.61
	Average across all occupation	4.02	5.07	3.42	3.01

*Source: US BLS O*Net and 2012 OES Research Estimates by Industry and State; author's calculations.*

Appendix Table 6

Skill requirements of Food Processing and Production Core Occupations

SOC	Occupation description	Education	Experience	On-the-job training	In-plant or on-site training
51-9111	Packaging and Filling Machine Operators and Tenders	2.05	3.12	3.07	2.77
51-3011	Bakers	2.26	4.51	2.62	2.51
51-3092	Food Batchmakers	1.92	2.68	3.15	2.60
53-7064	Packers and Packagers, Hand	2.09	2.38	1.87	1.99
51-9198	Helpers--Production Workers	1.77	3.63	2.28	2.34
51-3022	Meat, Poultry, and Fish Cutters and Trimmers	1.35	2.66	3.39	2.64
49-9041	Industrial Machinery Mechanics	2.81	6.60	4.95	4.65
51-3093	Food Cooking Machine Operators and Tenders	2.25	3.69	3.76	2.68
51-3099	Food Processing Workers, All Other	NA	NA	NA	NA
51-9192	Cleaning, Washing, and Metal Pickling Equipment Operators and Tenders	1.76	2.86	3.23	2.79
19-1012	Food Scientists and Technologists	6.81	3.72	3.40	2.72
19-4011	Agricultural and Food Science Technicians	4.42	4.55	3.20	2.96
	Average of core crossovers occupations	2.10	3.40	2.85	2.59
	Average across all occupation	4.02	5.07	3.42	3.01

*Source: US BLS O*Net and 2012 OES Research Estimates by Industry and State; author's calculations.*

Appendix Table 7

Skill requirements of Medical Equipment and Supplies Core Occupations,

SOC	Occupation description	Education	Experience	On-the-job training	In-plant or on-site training
51-2092	Team Assemblers	2.07	2.99	2.76	2.75
51-9081	Dental Laboratory Technicians	2.76	4.22	3.94	3.34
51-9082	Medical Appliance Technicians	4.43	5.70	4.38	4.21
51-4081	Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic	2.19	5.05	4.80	3.08
51-4041	Machinists	2.94	6.12	4.65	4.14
17-2031	Biomedical Engineers	7.70	4.25	3.25	3.25
17-2112	Industrial Engineers	5.44	7.45	5.17	4.93
51-4033	Grinding, Lapping, Polishing, and Buffing Machine Tool Setters, Operators, and Tenders, Metal and Plastic	2.07	2.85	3.22	2.56
17-2141	Mechanical Engineers	6.52	7.94	4.07	3.42
11-9041	Architectural and Engineering Managers	6.71	9.62	5.20	4.64
51-6031	Sewing Machine Operators	1.57	3.42	2.74	2.91
51-2023	Electromechanical Equipment Assemblers	3.09	4.13	3.58	3.50
51-9199	Production Workers, All Other	3.15	3.36	2.83	3.46
11-3051	Industrial Production Managers	3.90	7.50	4.78	4.73
51-4122	Welding, Soldering, and Brazing Machine Setters, Operators, and Tenders	2.86	3.60	3.13	3.00
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	2.28	4.64	3.60	2.43
	Sector weighted mean	3.35	4.67	3.74	3.39
	Weighted average across all occupations, by employment	4.02	5.07	3.42	3.01

*Source: US BLS O*Net and 2012 OES Research Estimates by Industry and State; author's calculations.*

Appendix Table 8

Skill requirements of Paper and Printing Core Occupations

SOC	Occupation description	Education	Experience	On-the-job training	In-plant or on-site training
51-5112	Printing Press Operators	2.14	5.07	3.23	2.68
51-9196	Paper Goods Machine Setters, Operators, and Tenders	1.76	4.06	3.31	3.19
51-5113	Print Binding and Finishing Workers	NA	NA	NA	NA
51-1011	First-Line Supervisors of Production and Operating Workers	3.47	8.61	4.65	3.84
51-9032	Cutting and Slicing Machine Setters, Operators, and Tenders	1.95	3.63	2.78	2.36
51-9198	Helpers--Production Workers	1.77	3.63	2.28	2.34
51-5111	Prepress Technicians and Workers	3.46	6.56	3.16	2.50
53-7063	Machine Feeders and Offbearers	2.15	2.23	2.28	2.15
11-3051	Industrial Production Managers	3.90	7.50	4.78	4.73
51-9121	Coating, Painting, and Spraying Machine Setters, Operators, and Tenders	1.82	5.07	3.33	3.50
51-9199	Production Workers, All Other	3.15	3.36	2.83	3.46
51-9194	Etchers and Engravers	2.28	3.72	3.75	3.35
51-4031	Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic	1.85	3.08	3.08	2.89
51-4111	Tool and Die Makers	3.42	7.60	4.90	4.56
51-9031	Cutters and Trimmers, Hand	2.10	5.33	3.53	3.23
51-9191	Adhesive Bonding Machine Operators and Tenders	1.80	4.42	3.98	3.18
	Average of core crossovers occupations	2.32	4.99	3.30	2.94
	Average across all occupation	4.02	5.07	3.42	3.01

*Source: US BLS O*Net and 2012 OES Research Estimates by Industry and State; author's calculations.*