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Reinventing Manufacturing

How the Transformation of Manufacturing Is Creating New Opportunity for California

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About the Institute

Since 1990, the Bay Area Council Economic Institute has been the leading think tank focused on the economic and policy issues facing the San Francisco/Silicon Valley Bay Area, one of the most dynamic regions in the United States and the world's leading center for technology and innovation. A valued forum for stakeholder engagement and a respected source of information and fact-based analysis, the Institute is a trusted partner and adviser to both business leaders and government officials. Through its economic and policy research and its many partnerships, the Institute addresses major factors impacting the competitiveness, economic development and quality of life of the region and the state, including infrastructure, globalization, science and technology, and health policy. It is guided by a Board of Trustees drawn from influential leaders in the corporate, academic, non-profit, and government sectors. The Institute is housed at and supported by the Bay Area Council, a public policy organization that includes hundreds of the region's largest employers and is committed to keeping the Bay Area the world's most competitive economy and best place to live. The Institute also supports and manages the Bay Area Science and Innovation Consortium (BASIC), a partnership of Northern California's leading scientific research laboratories and thinkers.

About BASIC

The Bay Area Science and Innovation Consortium (BASIC) is an organization of the Bay Area's leading research and innovation companies and institutions, which together constitute the world's greatest body of technology innovation capacity. Its participants include public and private universities, national laboratories, and leading private sector companies. BASIC's mission is to advance the science, technology and innovation leadership of the Bay Area, California and the nation. By bringing together the university technologists, laboratory directors, CEOs and CTOs who lead the region's world renowned research organizations, this unique multi-sector collaboration provides a platform through which the Bay Area's science and innovation community identifies and addresses issues and opportunities impacting the region's innovation leadership and its role as the world's leading marketplace for ideas.

Contents

California—with its diverse economy and history of innovation—is well positioned to capture future growth in many manufacturing sectors, but state and local governments will need more targeted policy tools to stimulate commercialization of new products, close the workforce gap, and incentivize more manufacturers to locate within the state. While the offshoring of production and automation technology have fundamentally transformed the industry, high-skilled manufacturing jobs are essential to a balanced, competitive economy. Today, advanced manufacturing techniques, the growing maker movement, and a renewed national interest in research and development have led to a reinvention of the manufacturing industry.

Executive Summary

Technology is revolutionizing manufacturing processes through innovations in 3D printing, robotics and big data (the Internet of Things)—often based on innovations that come from California. A range of factors, including rising labor costs in China, are leading some manufacturers to bring production home. California is in a good position to capture much of this growth, but needs policies that support and incentivize investment.

Throughout much of the 20th century, the US economy was buoyed by the manufacturing sector, which provided a source of middle-income jobs and drove new waves of innovation. Offshoring and recession have had major impacts on the sector, causing employment to shrink. However, technological advances and shifting global cost factors are now creating new opportunities for domestic manufacturing.

With more manufacturing jobs than any other state,[1] California has a diverse manufacturing base. Its innovation ecosystem, which has led to links between manufacturers and technology companies, makes it particularly well positioned to take advantage of a resurgent interest in domestic manufacturing. This is especially true for products of an advanced technological nature and products that depend on custom design and rapid response to markets.

Due to technological change, which has reduced the number of workers required for most production processes, this manufacturing renaissance is unlikely to generate jobs at the high levels it did in the past; however, it is central to a balanced economy and, if supported, can be an important source of economic competitiveness and high quality employment.

Major Drivers of Change

Manufacturing is undergoing a major transformation. These changes are creating both opportunities and competitive challenges comparable to those brought about by the invention of the steam engine and the Internet, and a third industrial revolution is already being triggered. Five forces in particular will impact California's manufacturing sector.

Shifting Consumer Expectations: The rise of the Internet has created growing numbers of "connected consumers" and a world in which consumers want customized services and products with shorter delivery times. From the way businesses interact with customers to the high service level customers have come to expect, the relationship between users and producers will become more engaged and will change the product and service innovation process.

Globalization: As wages rise, China is losing its status as the low-cost manufacturing country of choice, and companies are reevaluating their facility location options. Some are considering reshoring their manufacturing operations closer to Western markets. This has led to a growing conversation about the rejuvenation of domestic manufacturing.

Technological Advances: Advances in additive manufacturing (3D printing) and increasingly smart, flexible automation are upending traditional production models and facilitating the development of low-volume, high-cost products or highly customized applications such as medical devices and aerospace and defense parts.

New Productivity Levers: The expansion of "lean manufacturing" and the growing role of sensors and data analytics (the Internet of Things) in manufacturing applications are delivering value for manufacturers, producing efficiency gains and increased revenue through improved customer experience and value-added services.

Changing Workforce Dynamics: As production complexity continues to increase, manufacturers will need skilled workers who can operate and maintain the machinery. The replacement of existing infrastructure with smart manufacturing ecosystems will also lead to a ripple effect creating indirect jobs in markets that supply, support and service these operating environments. With this shift from direct to indirect jobs, the role of the manufacturing plant will shift from being a central employment hub for workers to becoming the nucleus of a larger network which employs people in a range of other industries that provide supply, support, and services to the manufacturing operation.

California's Shifting Landscape: Manufacturing and the Innovation Ecosystem

Since the last economic downturn, manufacturing employment in California has been growing. While overall manufacturing in the state has experienced declines similar to national trends since 1990, in the 2010–2014 period manufacturing employment has grown, though not as fast as employment overall. Between 2010 and 2014, total manufacturing employment expanded by 3.1 percent in the state. (Total state employment grew by 9.2 percent.) Employment gains were seen in 14 of 18 manufacturing sectors.

The following five manufacturing sectors met or exceeded California's overall rate of growth in the period from 2010 to 2014:

Beverage Manufacturing, +19.9 percent, +8,295 jobs

Pharmaceutical & Medicine Manufacturing, +9.1 percent, +3,917 jobs

Medical Equipment & Supplies Manufacturing, +9.1 percent, +4,499 jobs

Fabricated Metal Manufacturing, +12.6 percent, +14,387 jobs

Machinery Manufacturing, +10.0 percent, +6,508 jobs

Of those five sectors, the growth in the first three (Beverage Manufacturing, Pharmaceutical & Medicine Manufacturing, and Medical Equipment & Supplies Manufacturing) has led to job gains in California over the long term period from 1990 to 2014:

Pharmaceutical & Medicine Manufacturing expanded by 83.8 percent, totaling 46,877 jobs in 2014.

Beverage Manufacturing expanded by 46.6 percent, totaling 50,035 jobs in 2014.

Medical Equipment & Supplies Manufacturing expanded by 19.4 percent, totaling 53,922 jobs in 2014.

Following a trend similar to employment, the number of manufacturing establishments in California increased in the late 1990s and then steadily declined until 2013 when establishment growth resumed.

Manufacturing wages in California are rising. While total manufacturing employment in 2014 was 39.5 percent below where it was in 1990, inflation-adjusted average annual wages were 42 percent higher. Between 1990 and 2014, average annual incomes in manufacturing increased at a faster rate than the economy as a whole, where incomes rose by 24 percent. This suggests that the structural shifts that have taken place in manufacturing in recent decades have resulted in the need for fewer but more highly qualified workers.

Manufacturing is distributed across the state, with distinctive regional clustering. Although manufacturing clusters are concentrated in urban centers, especially in Southern California, there are also pockets of producers in the state's rural areas. The eight regions defined in this analysis demonstrate distinct manufacturing strengths and trends, and each has evolved in a different way since 1990.

> The *Los Angeles Area* is California's largest manufacturing hub. With 478,919 manufacturing jobs, the region accounted for 38.5 percent of the state's manufacturing employment and 8.4 percent of the Los Angeles Area's total employment in 2014.
>
> The *Bay Area* is a leading global hub of technology innovation. Although it is one of the most expensive regions of the state, many manufacturers locate there because they work closely with the region's technology companies. The Bay Area's 293,847 manufacturing jobs made up 23.6 percent of manufacturing employment in California and 8.4 percent of Bay Area employment in 2014.

Orange County is the third largest manufacturing region in California, with 141,810 manufacturing jobs in 2014. It also has the highest concentration of manufacturing employment in the state, with manufacturing jobs accounting for 10 percent of the region's employment.

California's *Central Valley* is the heartland of the state's food production activity. Clustered around the cities of Bakersfield, Fresno, Modesto, and Stockton, its manufacturing sector accounted for 98,038 jobs in 2014 and 6.9 percent of total employment in the region.

Manufacturing accounted for 6.2 percent of total employment in the *San Diego Area* in 2014. Of the 84,615 manufacturing jobs in the region, a large portion are defense related.

Manufacturing accounted for 23,460 *Central Coast* jobs in 2014 and 4.1 percent of total employment in the region.

The 21,145 manufacturing jobs in the *Sacramento Area* accounted for only 2.4 percent of jobs in the region in 2014—the lowest regional share in the state.

In 2014, manufacturing accounted for 13,491 jobs in the *Northern California* region, or 4.0 percent of the region's employment.

Strengthening California's Environment for Manufacturing

Specific actions can be taken to support the growth and advancement of manufacturing in the state and to develop the workforce its producers need.

Stimulate the commercialization of research and development through cluster-based strategies. Better coordination of California's research institutions with business activities could help advance the state's manufacturing ecosystem by supporting economic assets already in place and leveraging existing innovation networks to drive the commercialization process.

Grow the talent base for advanced manufacturing. Advanced manufacturing requires advanced workforce skills. As the existing manufacturing workforce ages and nears retirement, recruitment poses a major challenge for producers of advanced products or those utilizing advanced processes. Initiatives are needed to match workforce training with the needs of manufacturing employers, through apprenticeship and career technical education programs and a statewide certification system geared to advanced manufacturing skills.

Provide access to capital and financial incentives for manufacturers. To create a stronger market for investment in the state's manufacturing base, especially in small manufacturers, California could employ a tax credit for investments made in the sector. If the benefits of the Industrial Development Bonds program are marketed more aggressively through local economic development channels, more manufacturers will be encouraged to take advantage of low-cost capital when expanding or moving their operations. Since prototyping can be costly for entrepreneurs and new companies that lack access to expensive manufacturing tools, the creation of local facilities that provide access to manufacturing equipment can help small manufacturers conserve resources and move their products more quickly to market.

Address the cost of doing business in California for manufacturers. Industrial land use policies can alleviate land availability issues, particularly as housing and other commercial uses encroach. Limiting windows for CEQA challenges and creating special manufacturing zones at the local level, such as Industrial Priority Corridors, can give manufacturers greater certainty when making long-term investments.

PART One

Technology is revolutionizing manufacturing processes through innovations in 3D printing, robotics and big data (the Internet of Things)—often based on innovations that come from California. A range of factors, including rising labor costs in China, are leading some manufacturers to bring production home. California is in a good position to capture much of this growth, but needs policies that support and incentivize investment.

Throughout much of the 20th century, the US economy was buoyed by the manufacturing sector, which provided a source of middle-income jobs and drove new waves of innovation. Offshoring and recession have had major impacts on the sector, causing employment to shrink. However, technological advances and shifting global cost factors are now creating new opportunities for domestic manufacturing.

With more manufacturing jobs than any other state, California has a diverse manufacturing base. Its innovation ecosystem, which has led to links between manufacturers and technology companies, makes it particularly well positioned to take advantage of a resurgent interest in domestic manufacturing. This is especially true for products of an advanced technological nature and products that depend on custom design and rapid response to markets.

Due to technological change, which has reduced the number of workers required for most production processes, this manufacturing renaissance is unlikely to generate jobs at the high levels it did in the past; however, it is central to a balanced economy and, if supported, can be an important source of economic competitiveness and high quality employment.

1

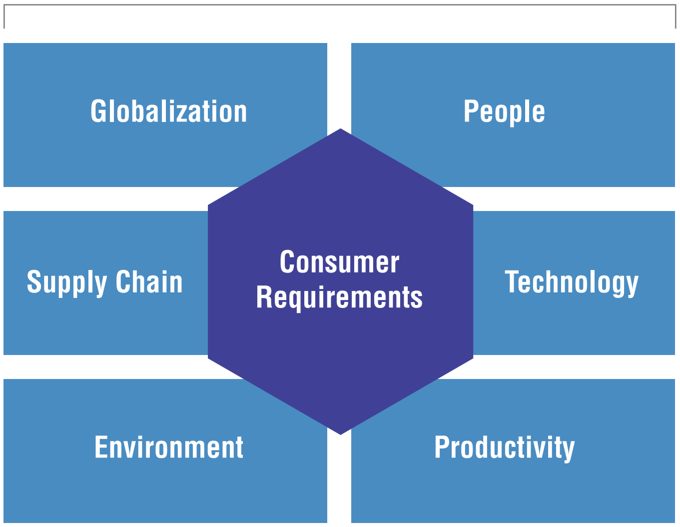
Major Drivers of Change

Manufacturing is undergoing a significant transformation as new technologies begin to enable new consumer expectations. The resulting wave of change will create both opportunities and competitive challenges comparable to those brought about by the invention of the steam engine and the Internet, and a third industrial revolution is already being triggered.

Simultaneously, manufacturing is increasingly becoming a hot topic in both public debate and in private boardrooms. For the past several years, US policy makers have been speaking of a manufacturing renaissance, promoting its potential for increased output and job creation while looking for ways to attract further investment from US and foreign manufacturers. As an example, President Obama's administration, through its "Make It In America" campaign, is actively encouraging companies to move manufacturing from overseas locations back to the United States, hoping to create more jobs and increase the country's international competitiveness.

Manufacturing company executives constantly wrestle with strategic and interrelated questions that affect what, where, and how they make their products. Where should we add capacity? How can we incorporate big data to improve productivity and customer satisfaction? Given how quickly products and technologies change, what is the level of automation that we should employ? What skill sets should we acquire or develop? To answer these questions, they increasingly need to look beyond their immediate activities and take into account the total picture of forces that impact manufacturing.

Figure 1: Forces Impacting Manufacturing



Source: A.T. Kearney

Seven major forces are driving the global change in manufacturing.

Consumer Requirements: The prime driver of change is the ever-rising level of consumer expectations. The always-connected consumer expects a highly personalized product available in short order. Enabled by transformations in online retail and omnichannel fulfillment, these expectations are rapidly making their way back upstream to product design. The same high expectation dynamic is present in B2B settings.

People: New workforce dynamics are evolving as a shrinking manufacturing talent pool, emerging new technologies and increased use of big data are driving the need for new skill sets and different ways to deploy and manage the workforce.

Technology: The traditional, manual and reductive manufacturing model is being reshaped by new additive manufacturing and automation technologies.

Productivity: Lean product development and lean supply chain efforts are reaching a new level of productivity enabled by the richness of data generated by the Internet of Things.

Globalization: The global economy continues to change the dynamics of production and consumption. The wage differentials that historically drove businesses to move manufacturing to Asia are shrinking, causing companies to re-evaluate their location choices and reconsider production in or closer to their end markets.

Supply Chain: Global value chains are becoming more efficient, effective and agile as information exchange allows companies to focus more on their core competencies while collaborating with suppliers and/or partners for other value chain needs.

Environment: Forces of nature and governmental policies both expose global supply chains to risks that impact their ability to produce and deliver goods. Simultaneously, alternative sources of energy are changing the economics of production locations.

The ability to interpret, adapt and respond to these underlying forces will differentiate manufacturing winners from losers in the coming decades.

Five specific forces will have the greatest impact on California's manufacturing sector:

Shifting Consumer Expectations: The rise of connected consumers and their desire for shorter delivery times will change the relationship between users and producers.

Globalization: Rising labor costs in China that are narrowing cost differentials with the US will contribute to shifts in the manufacturing roles of various regions.

Technological Advances: The disruptive impact of additive manufacturing and automation will test and reshape traditional manufacturing processes.

New Productivity Levers: The expansion of "lean manufacturing" and the growing role of the Internet of Things in manufacturing applications will create a new productivity environment.

Changing Workforce Dynamics: Manufacturers will be faced with a growing skills gap and a future need for new indirect roles and skill sets.

Shifting Consumer Expectations

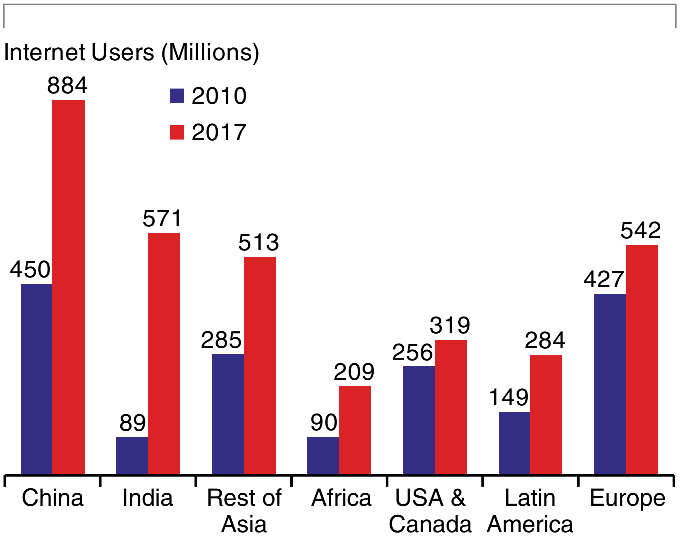
From the way businesses interact with customers to the high service level customers have come to expect, the relationship between users and producers will become more engaged and will change the product and service innovation process.

The Rise of the Connected Consumer

The Internet revolution has created 24/7 human connection and communication that continues to take on new forms. Internet users are expected to almost double from 1.7 billion in 2010 to 3.3 billion in 2017: Asian countries will be the largest contributors to this growth (see Figure 2), accounting for about 73 percent of it.

With continuous Internet connectivity, consumers have at their fingertips the power to browse through large numbers of product and service offerings and pick the ones that are just right for them. This growing consumer power will dictate how businesses cater their products and services and the modes in which these are delivered. From the manufacturer's standpoint, increased connectivity means a higher opportunity to engage with and win over a customer.

Figure 2: Internet Users by Region



Source: The Economist Intelligence Unit

A Connected Consumer survey, conducted by A.T. Kearney's Consumer Products & Retail Practice in July 2014, found that connected consumers spend most of their online time using social media, with social networking accounting for 46 percent of connected consumer online time globally. (Of the remainder of consumer online time, 28 percent is being spent on online entertainment, 18 percent on shopping, and 13 percent on transactional services.)[2]

This social-media-fueled connectedness generates a vast quantity of "demand signals" and information (data) that may contain valuable insights on consumer behavior and consumption patterns. The gathering and processing of big data will help manufacturers and other members of the value chain improve their ability to respond to and even predict the needs of the ever more fragmented and fickle customer base.

Internet-empowered consumer connectedness has also created a world in which consumers want customized services and products. To meet customers' unique needs and desires, companies are striving to deliver more personalized products by facilitating mass customization—the production of "one-offs" on demand. For several decades, mass customization has been a topic of future promise, but lately it has become more realistic as technologies like 3D printing and customer interaction platforms enable cost-effective ways to create customized offerings.

The rise of the connected consumer creates an ecosystem in which new companies and products can make their way onto a consumer's radar screen and receive immediate feedback which, in turn, can significantly reduce the cost and risk of innovation. For established players, this means an enhanced level of competition to maintain a healthy flow of new products and services.

In order to increase the cadence of product and service innovation, companies will need to translate the big data generated via digital platforms into insights that they can use to create new product or service features. This change in the innovation process will result in a more integrated approach to design, where internal functions—like manufacturing, marketing and R&D—leverage external sources, customers and suppliers to co-create the next generation of products.

Shorter Delivery Lead Times

Next day delivery is a thing of the past. Think, browse, buy and get within an hour will emerge as the norm in this age of instant gratification. As explored in a recent study by A.T. Kearney's Health Practice,[3] consumers today are benefiting from a new competitive landscape in which traditional delivery service companies like UPS and FedEx compete with alliances from other powerhouses and other market entrants:

Google and Target are teaming up to offer same day delivery.

USPS and Amazon are pairing up to offer grocery delivery and Sunday deliveries.

Amazon is testing drone deliveries in trend-setting states allowing them.

Disruptor companies like UberRUSH are pioneering on-demand delivery.

This competitive landscape has significantly improved delivery service levels but has also squeezed margins for transportation companies. A big driver of this change has been Amazon and its free shipping offer, which is now replicated by most online retailers. In 2000, Amazon introduced free shipping on orders over $100. This offering was expected to fade away but it did not, since other retailers followed the move and made free shipping standard.

Going forward, consumers will continue to expect even higher levels of service as last mile delivery happens within an hour in a secure and cost effective manner for both the retailer and consumer. To enable this level of order fulfillment, stores will continue their evolution towards becoming integrated distribution and pickup points.

The continued need for higher service levels and shorter response times will impact how supply chains evolve and how manufacturers think of their products, footprints, and processes. Distribution points will need to be closer to consumption; order quantities will be smaller and replenishment cycles will be shorter; product design and packaging will need to be optimized for delivery; and more manufacturers will need to have more flexible operations or be closer to the consumer or both.

Disrupting technologies like drones and self-driving cars will further fuel the "need for now" and alter the economics of last mile delivery providers. These changes are being enabled by new laws: The FAA is expected to regulate drone deliveries within two years, and the State of California just vetoed the restriction of drone use in residential areas.

Manufacturing technologies like 3D printing and robotics will be integrated into the quick delivery solution to help with some of these challenges, and their implications are explored later in this document.

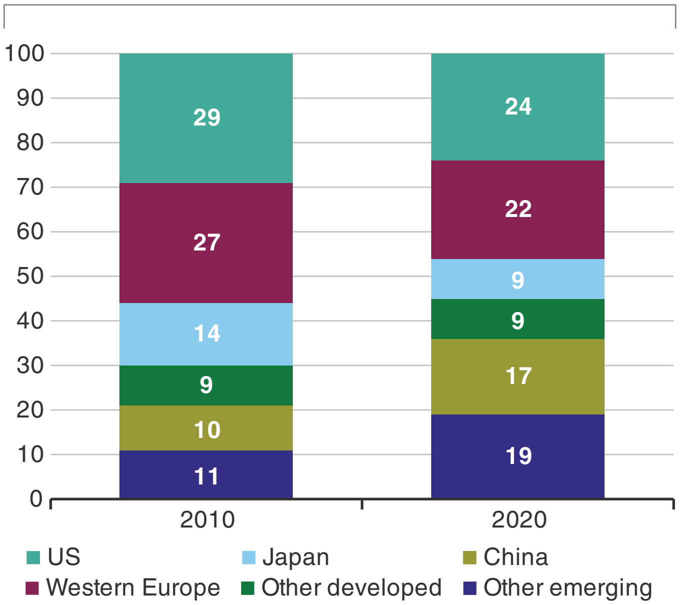
Globalization

The global economy is in constant movement and the manufacturing roles of various regions are shifting.

The Emerging Global Middle Class

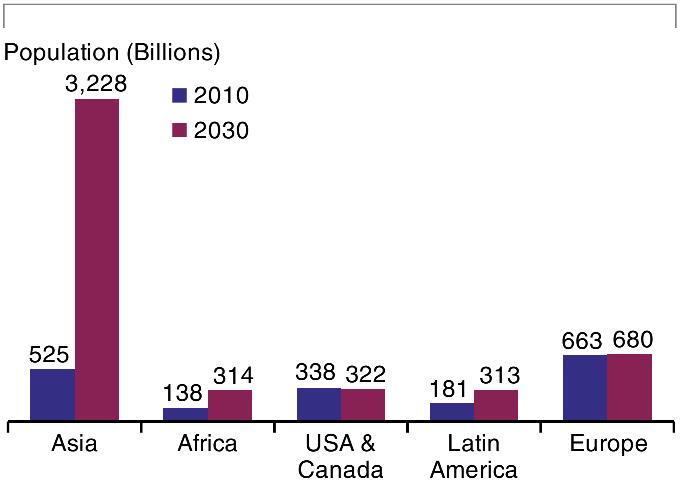
As the transition from a West-centric to a diversified global economy continues, China and other emerging markets' share of global financial assets is expected to move from the current ~21 percent to ~36 percent by 2020. (See Figure 3)

Figure 3: Projected Share of Global Financial Assets



Source: Office of the Director of National Intelligence

Figure 4: Middle Class Population Projections



Source: World Bank; Brookings Institution

This wealth shift is driven largely by the accelerating growth of an emerging "global middle class," as working class wages increase, giving workers economic access they didn't have before (see Figure 4). This will be a particular characteristic of China and India, which are both expected to see the size of their "middle class" income groups more than double by 2030.

By 2030, over 70 percent of China's population will have entered the "middle class," consuming nearly $10 trillion in goods and services. Similarly, India could be the world's largest middle class consumer market by 2030, surpassing both China and the US.

The implications of this transition are twofold. First, manufacturing and logistics networks that have historically been optimized primarily to supply the West will face demand from Eastern markets. Manufacturing assets, which are still largely based in Asia, will therefore increasingly serve local markets. This change in focus paired with higher overall demand on the same assets will likely result, at least in the short term, in increased product cost and/or slower delivery response time to serve Western customers.

Second, the wage differentials that historically drove Western companies to move manufacturing to Asia are shrinking, causing these companies to reevaluate their facility location choices and consider reshoring their manufacturing operations closer to Western markets. The United States, United Kingdom and even Italy are increasingly seeing manufacturers return to in-region operations.

The Rebalancing of Global Value Chains

China continues to be an important provider of manufactured goods. However, due to ongoing annual labor cost increases of 10–20 percent, China is quickly losing its status as the low-cost manufacturing country of choice. This will change the role played by China in global manufacturing, as less complex and cost-sensitive production moves to other countries.

But its global leadership position will continue in a different form as China develops and reshapes its manufacturing capabilities. A shift away from low-technology and low-productivity to high-technology and high-productivity manufacturing is already occurring, though at a fairly moderate pace, as many Chinese companies adopt lean techniques and automation to compensate for higher labor costs.

This effect is already underway in sectors like Automotive where labor-intensive, low-tech production is moving to countries with lower labor costs, such as Vietnam and Bangladesh. Meanwhile, the flow of high-end production from Western countries to China–mainly spurred by local market growth, an acceptable productivity and labor-cost ratio, and a strong supplier base–is overcoming hurdles like IP risks, underdeveloped infrastructure (inland) and an opaque political environment, to change the landscape and role of Chinese manufacturing.

As the economics change and the manufacturing role of China and other Asian countries shifts, the idea of a massive return of manufacturing activity to developed countries has gained prominence. For the past 3 years, the US has seen growing buzz about the promising rejuvenation of manufacturing, fueled largely by a wave of manufacturing reshoring. This shift has not yet occurred on a large scale, but a trend to bring manufacturing back to the US is becoming more evident.

The US reshoring trend is underpinned by many economic and business factors including changes in labor costs, increased concerns about supply disruption, lower energy cost in the United States (partially as a result of shale gas exploration), and a general push from US federal and state governments to reduce administrative barriers and the costs of bringing manufacturing back.

To better understand this trend, A.T. Kearney analyzed close to 700 reshoring cases that have been published over the past 5 years. In the latest update of its Reshoring Database,[4] reshoring activity has been documented across many sectors, including some where reshoring was expected (Electrical Equipment, Appliance, & Component Manufacturing; Computer & Electronic Product Manufacturing; Plastics & Rubber Products Manufacturing; Machinery Manufacturing; Fabricated Metal Product Manufacturing; Primary Metal Manufacturing; and Furniture & Related Product Manufacturing), but also sectors that most thought would never return, like Apparel Manufacturing (see Figure 5), which would be hard to explain if only macro-economic factors were at play.

Analysis of documented reshoring cases shows that companies can have different reasons to reshore (see Figure 6) and use different approaches to making it happen, even within the same industry. Customers expecting shorter lead times and companies becoming more worried about the quality of their products are forcing executives to rethink their supply chains. Also, some companies are bringing back manufacturing for the same reason they offshored it in the first place: cost! "Made in USA" is making a comeback as a tag line to boost sales and, as a result, is moving up in the ranking for reasons to reshore, particularly in the last two years.

Figure 5: Top Reshoring Industries

	Percent Cases
Electrical Equipment, Appliance, & Component Manufacturing	15%
Transportation Equipment Manufacturing	15%
Apparel Manufacturing	12%
Computer & Electronics Product Manufacturing	10%
Miscellaneous Manufacturing	7%
Plastics & Rubber Products Manufacturing	7%
Machinery Manufacturing	5%
Fabricated Metal Product Manufacturing	5%
Primary Metal Manufacturing	3%
Furniture & Related Product Manufacturing	3%
Chemical Manufacturing	2%
Other Manufacturing	8%
Other non-manufacturing	8%

Source: A.T. Kearney Reshoring Database

Figure 6: Top 10 Reasons for Reshoring

	Percent Mentions
Delivery Time Improvement	30%
Quality Improvement	29%
Image/Brand (prefer US)	20%
Freight Cost Improvement	20%
Wage Cost Improvement	20%
Total Cost Ownership	17%
Energy Cost Improvement	14%
Government Incentives	14%
Innovation/Product Differentiation Improvement	13%
Higher Productivity	13%

Source: A.T. Kearney Reshoring Database

Technological Advances

Manufacturing technology is testing and reshaping the traditional processes of reductive manufacturing, multi-component assembly, and manual labor in favor of more efficient and high-performing processes based on additive manufacturing and increasingly smart, flexible automation.

Additive Manufacturing

With more than thirty years of technological development, additive manufacturing, also referred to as 3D printing, has quietly promised to revolutionize manufacturing; only recently, however, has this formerly underground fervor gained mainstream media attention. Despite the tendency for enthusiasm about its potential to get ahead of its practical applications, additive manufacturing is already providing traditionally high-cost regions with an opportunity to regain manufacturing competitiveness.

Today, production level applications of 3D printing are primarily attractive for low-volume, high-cost products or highly customized applications such as medical devices and aerospace and defense parts. This early adoption, however, is driving technology, infrastructure, and cost improvements that are making additive manufacturing increasingly competitive for larger batch sizes and broader applications. The technology also enables design-to-buy product development by allowing an unprecedented level of product personalization. As investments and advancements continue, financial markets are responding: stock valuations in the sector are growing, private equity is increasingly moving money into 3D printing companies, and M&A activity is picking up.

While this momentum is likely to create a tipping point in the next few years, the definitive answer to the question "How can I use additive manufacturing to create a competitive advantage for my company?" still remains elusive for most executives. Manufacturing leaders must continue to monitor advances in the field, particularly as three advantaged characteristics become more prominent: unconstrained design, variable cost manufacturing, and end user value creation.

Unconstrained Design

Four applications will allow the full potential of additive manufacturing to come to life.

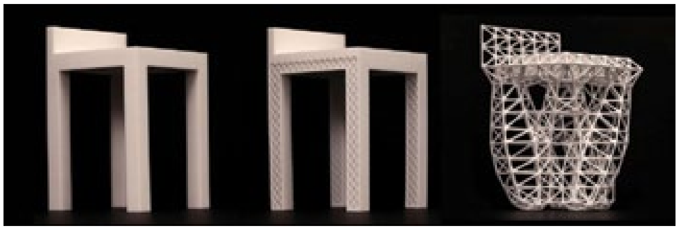
Prototype Iteration: With additive manufacturing, not only can prototypes be made with limited machine downtime, but production tooling itself can be 3D printed and can more readily adapted to the evolving iterations of prototypes.

Customization: By dramatically reducing the timelines needed for customization, additive manufacturing will allow potentially unlimited ways for innovative companies to create customer-specific products in lot sizes as small as one.

Design Extension: Value-added design features that are too costly to implement with current production methods, such as internal webbing for dramatically improved strength-to-weight ratio, become not only possible, but prolific (see Figure 7).

New Algorithms: Algorithms that seek to improve customer experience and product value will emerge as advanced computing companies develop programs that generate designs based on functional requirements.

Figure 7: Design Extension for Improved Strength-to-Weight Ratio



Images courtesy of Autodesk

In collaboration with Autodesk, architect David Benjamin started with a simple solid chair (left), applied design software to reduce weight (center), and then fed the design constraints (e.g., the weight the chair must bear) into a 3D design system capable of evaluating an infinite number of ways to build the same product. The result (right) was a stronger seat weighing 70% less than the solid chair.

Variable Cost Manufacturing

Two evolving characteristics will drive continued improvement in the economics of additive manufacturing.

Decentralized Agility: Additive manufacturing has the potential to enable a more agile, responsive value chain that can deliver favorable combinations of customization, cost, and speed.

Low Barriers to Entry and Exit: Enabled by additive manufacturing, software-driven operating models including open innovation and agile development will drive manufacturing innovation through collaboration, low barriers to entry, and scalability.

End User Value Creation

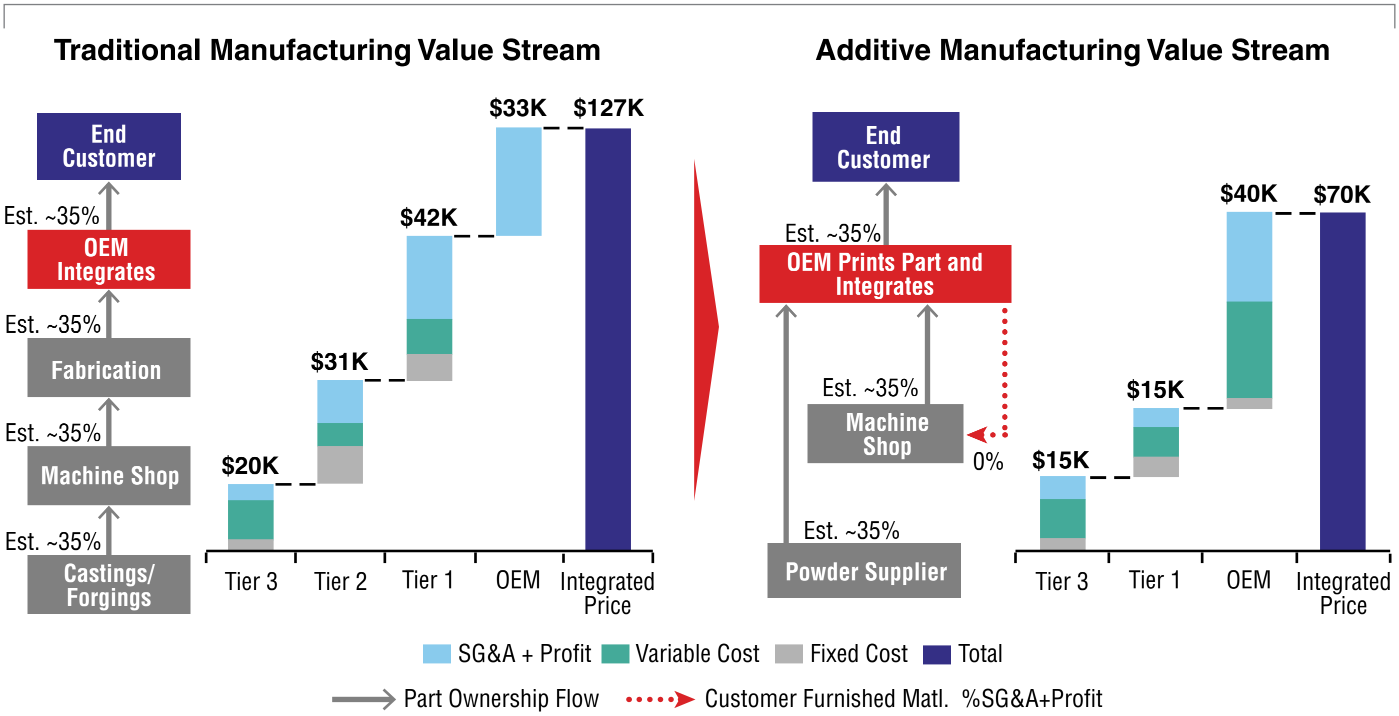
In the pursuit of value for the end user, additive manufacturing will complement existing manufacturing in at least three areas.

Value Chain Reconfiguration: Disruption of the current "make vs. buy" decision paradigm will grow as corporations utilize 3D printing to bring some outsourced operations in-house while continuing to outsource others (see Figure 8). This will lead to a more optimized supply chain that translates into lower costs for end users.

Inventory/Obsolescence Management: Service levels will also benefit from an additive-manufacturing-driven value chain, as just-in-time fabrication can respond swiftly to demand for new and replacement parts.

Dynamic Competitive Sourcing: In an additive-manufacturing-driven value chain, a supply manager would be able to more granularly segment the product portfolio into sourcing families that suppliers can qualify for based on common characteristics, such as manufacturing processes, material, production volume, etc.

Figure 8: Aerospace Illustration—Scaled Turbine Exhaust Case Single Unit Production



Traditional Manufacturing Value Stream

Additive Manufacturing Value Stream

Source: A.T. Kearney

Automation

When we think of robots, many of us think of everything from R2-D2 to hulking machines that weld together automotive parts to autonomous vacuum cleaners that scurry around cleaning our living room floors. Industrial robots, however, are at the onset of a new wave of innovation with the potential to significantly alter the manufacturing floor and with it, industry. Manufacturers are moving beyond the large, expensive, caged robots that tirelessly perform simple, repetitive tasks in a fixed system, into a new era of "collaborative robots" or "co-bots." These co-bots work alongside humans on the manufacturing floor to enhance safety, precision and productivity in an increasing number of applications and without fundamental redesign of the flows in the factory.

Distinct from simple automation, robots, and especially co-bots, can work in unstructured environments, making use of sensors, vision software, sonar, and autonomous navigation technology to take on tasks that formerly only a human could do. Robots can relieve workers of straining or dangerous factory tasks and can often perform tasks faster and more precisely than a human could. While robots are becoming capable of an increasing array of tasks, in recent years, approximately three quarters of industrial robots in use specialize in three tasks: handling operations (38 percent), welding (29 percent) and assembly (10 percent).[5] These tasks are simple and repetitive, generally performed in a sectioned-off portion of the plant, and the robots are monitored locally by trained technicians and programmers.

The cost of traditional industrial robots has fallen dramatically in recent decades in comparison to human labor compensation, but it remains high relative to the new wave of co-bots. A traditional robot could cost in excess of $100,000 for the machine itself and would generally require at least twice that in additional expenses to program, install and set up the machine on site.[6] The new collaborative robots can cost less than $30,000 and can be set up for an initial task in as little as an hour, without requiring any reconfiguration or extended disruption of the manufacturing floor. Such low capital expenditure means that robots now compare favorably on an hourly basis to human labor, even in lower-wage countries.

Co-bots have the added capability of being flexible, as they are able to switch among multiple tasks with little modification or reprogramming. Such flexibility enables shorter production runs with changeovers that are less complex and time consuming. In the European Union, the LOCOBOT consortium project to develop co-bots for the electric vehicle industry estimates that the industry will see near-term (2–5 years) benefits due to the increased efficiency and flexibility afforded by co-bots.[7]

While the prevalence of "lights out factories" (in which a facility runs fully automated) or the full deployment of co-bots may be a decade or more away, companies should be thinking now about how robots will come to change their industry and their own operations. As robotics technology continues to advance, as requirements for precision assembly increase, and as wages continue to rise, the trade-off will increasingly tip towards automation across industries and factory tasks.

INSIGHT

General Electric’s Industrial Internet: Moving from Smart to Brilliant

Lothar Schubert, *GE Digital*

Until very recently, hardware, software and data systems were developed for separate purposes, but when they are brought together, dramatic new possibilities arise. This convergence is called the Industrial Internet and its potential is enormous. With the Industrial Internet, analytics become predictive, employees increase productivity, and machines are self-healing.

While no two factories may look or act alike or have the exact same challenges, all of them are trying to achieve a common goal: optimal performance through intelligent decision-making and the effective management of resources—people, machines, tools and materials. In the past, manufacturers may have instrumented a critical piece of equipment or optimized one aspect of the manufacturing process. However, what we have learned is that connecting information upstream and downstream is critical when optimizing the factory. It is important to create a repeatable, consistent and cost effective approach to connecting machines, thereby providing the visibility necessary to form the foundation of the “Digital Thread” across the complete enterprise, where projects flex with business changes and priorities.

Uniting the physical and the digital—and the human and the machine—makes possible a new breed of manufacturing plant that can drive its own advance. GE calls this the “Brilliant Factory.” GE believes that the key to optimizing the full product life cycle from design to service is through analytics of data that has been traditionally locked inside corporate silos. In the Brilliant Factory, equipment and computers talk to each other over the Industrial Internet in real time, share information, and make decisions to preserve quality and prevent downtime. In such a factory, production lines are digitally connected to supply, service, and distribution networks to maintain optimal production.

The key components of the Brilliant Factory are advanced technologies, sensor-enabled automation, factory optimization, and supply chain optimization.

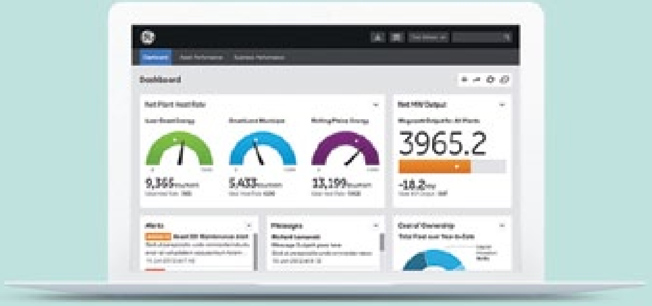
> **Advanced Technologies**: With laser-powered 3D printers, workers can rapidly prototype new solutions and accelerate the production of next-gen parts.
>
> **Sensor-Enabled Automation**: Throughout the factory, sensor-enabled machines collect data, enabling plant operators to prevent unplanned downtime and boost productivity.
>
> **Supply Chain Optimization**: Cross-business tools can reconfigure supply chain and factory operations to meet specific customer needs with more speed, standardization and savings.
>
> **Factory Optimization**: Data-driven human processes, robot-supported work and other operations can be changed in real time to maximize productivity and efficiency.

Finally, feedback loops are at the core of the Brilliant Factory, whether they come from GE plants or remanufacturing and service shops fixing parts after they have been used by customers for a long time. The feedback loop helps GE to understand whether the parts, as designed, could be manufactured with the specified features and materials, within acceptable cycle time, cost and yield. Equally important, after the parts have been in service, GE can find out how they looked and behaved. This information is then sent to GE’s design teams and to their own software-enabled design tools, so they can validate and learn.

Today, GE collects more data than ever before because of better sensors and better control systems, and the company has the capacity to analyze that data better than ever before because of advanced software and predictive analytics. By continuously changing the way we work, we are better able to take action and to understand how well our processes are working inside the factory. As part of GE's Brilliant Factory strategy, it is building the Digital Thread from product design through the supply chain and is leveraging the latest technologies to optimize operations in real time.

Capitalizing on 3D modeling tools, sensors, controllers, robotics, pillar software such as Product Lifecycle Management (PLM), Enterprise Resource Planning (ERP) and Manufacturing Execution Systems (MES), as well as using its Predix platform for machine data cloud connectivity, security and manufacturing analytics, GE is "digitally-enabling" its operations and gathering hundreds of gigabytes of data to gain new insights into how its machines are operating and how its processes are working on the factory floor. GE is also monitoring its vast distribution network and inventory supplies in ways never done before. The results have been incredibly impactful—driving increased productivity, reduced costs, reduced cycle time and improved quality. One of GE's Brilliant Factory sites in Greenville, South Carolina has estimated that more than $100 million in benefits have accrued over a 3-year period by building the Digital Thread from model-based engineering through sensor-enablement on the factory floor. As part of the Digital Thread strategy, GE will increase their machines and materials connectivity by 400% in 2016. Connecting the Digital Thread and utilizing the data in new ways is the foundation for making factories of the future brilliant.

As GE sees things, it is just starting to scratch the surface. The opportunity to apply new types of analysis to factories arrived over the last three or four years, especially with the emergence of the Industrial Internet and the ability to handle data sets on a very large scale. As one can imagine, when machining a part, drilling a hole or putting new materials together, a great deal of important data that was previously out of reach can now be collected. Being able to transmit that information, store that information, figure out which data points are important, and then do the analysis has been a huge step change in enabling the Brilliant Factory. It is a commitment to combing operational technology, the Industrial Internet, and the continuous changing of the way we work, to put the right solutions at the right places at the right time.



New Productivity Levers

Productivity will move beyond Lean and into an environment where sensors, data and analytics optimize operations in real time.

Going Beyond Lean

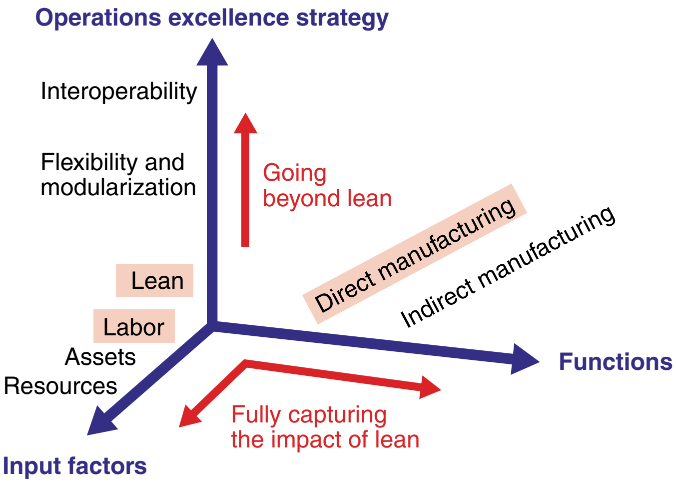
Since the early days of the Lean movement[8] epitomized by Toyota and described in the 1990 book *The Machine That Changed the World*, thousands of companies have launched initiatives to eliminate waste in their factories. However, with Lean in the mainstream, it is no longer a differentiating lever by which companies in developed countries can compete with those in low-labor-cost countries. The answer to what comes after Lean is threefold: (1) more Lean; (2) Lean in inputs and other functions; and (3) Lean beyond the company's walls.

First after Lean comes "more Lean," since many companies are still applying Lean to only a portion of their manufacturing operations, thereby leaving significant opportunity on the table. Within any given industry and market, significant productivity differentials continue to persist, and they prove that some players in that industry or market are more Lean than others. In addition, in markets that came later to the Lean game, such as China, "classic" Lean still has an important place on the management agenda, as labor costs are increasing quickly and basic Lean principles are increasingly being used to keep these costs somewhat under control.

Second, even for those who have rolled out Lean successfully across their own operations, there is still opportunity to look beyond their production and management systems to focus on input factors and supporting functions. While it is true that Lean is increasingly the standard (e.g., nearly all applications for A.T. Kearney's annual "Factory of the Year" benchmarking competition state Lean as a key element of driving performance in their operations), those standard Lean programs mostly focus on reducing shop floor labor costs and material waste. But Lean goes far beyond direct labor, as it starts with truly understanding the customer's needs and then focuses on delivering in a way that minimizes any kind of waste, not just waste in materials or labor. It incorporates assets, resource inputs, inventories, indirect manufacturing and even other company functions, from R&D up to Sales (see Figure 9).

Third, to achieve the next step change in productivity, manufacturing companies will have to push Lean beyond their walls. For example, consumer electronics companies face the challenge of reducing their time to market in order to outperform their competition. One way to do this is by maximizing operational flexibility by leveraging third parties and minimizing their own assets through better collaboration with suppliers, clients and other stakeholders in their ecosystem. By doing that, these companies effectively extend Lean beyond their internal operations to reach a more efficient level of interoperability among partner entities.

Figure 9: Lean Dimensions



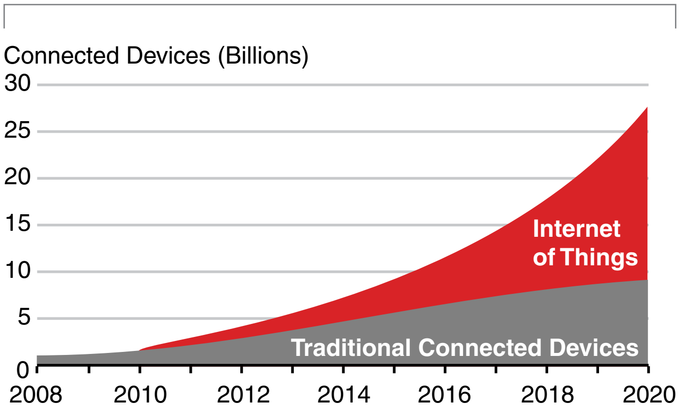
Source: A.T. Kearney

The Internet of Things (IoT) and Data Analytics

Another new paradigm of productivity is being enabled by the ubiquity of low-cost sensors, pervasive connectivity, and near unlimited computing power—collectively described as the "Internet of Things" (IoT).

The Internet of Things and the advanced use of data analytics will be pervasive. A.T. Kearney estimates that the number of IoT devices will go from half as many as traditional connected devices in 2013 to double that number by 2020 (see Figure 10).[9] This growth will translate to approximately 3.5 connected devices for every human being on the planet.[10] This adoption rate will vary by location, but in many communities within California—which is at the forefront of most things related to technology—the adoption rate is expected to be at the higher end.

Figure 10: Estimated Worldwide Growth of Traditional Connected Devices and IoT



Source: A.T. Kearney

As manufacturing industries start to incorporate an increasing number of sensors into their manufacturing processes, the amount of data being gathered will rise significantly. This increased visibility of the manufacturing process will create a positive feedback loop.

For manufacturers, the use of IoT will ultimately deliver value through a combination of three levers: (1) reduced cost through improved productivity and operational efficiency; (2) improved capital efficiency through lower asset downtime; and (3) increased revenue through improved customer experience and value-added services.

The applicability of these value levers can be expected to evolve over time (see Figure 11) and be realized in at least four types of applications.

Process Control: The use of sensors in manufacturing processes will grow in number and sophistication to provide higher resolution, precision and frequency of information to the process control brain which, in turn, will be able to more promptly and accurately correct the course of production and increase throughput and yield.

Asset Management: Sensors will enable real-time monitoring of machine performance. Maintenance programs and methods of the past will give way to continuous machine communication, the optimization of maintenance activity, and ultimately higher asset availability.

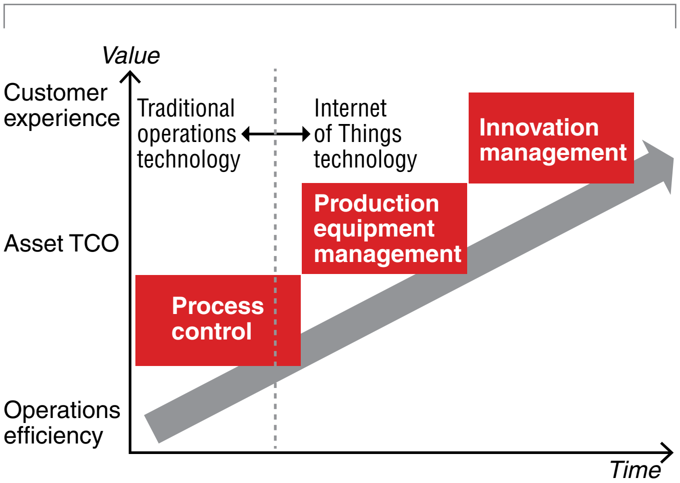
IoT in Production and Post-Production: Produced parts will also be able to communicate via embedded sensors and alter the course of production in real time. For example, a silicon wafer could know its own performance characteristics and needs for testing and could transmit that information to the manufacturing and quality testing process. In addition, once they leave the factory and become operational, sensors could also communicate their use and performance back to manufacturers. This will allow manufacturers to continuously improve the design and manufacturability of new products.

Inventory Management: The cost effectiveness and sophistication of sensors will eventually enhance current tracking technologies (e.g., Radio Frequency Identification) and increase the use of IoT technology to track inventory and the flow of goods within a manufacturing plant, a distribution network and a retail point of sale.

Before IoT becomes a reality in manufacturing, however, it needs to overcome a set of systemic hurdles that includes a limited near-term business case, lack of standards, security concerns, privacy concerns, and implementation complexity issues.

These hurdles are being tackled in different forms and shapes, including the creation of standards consortia and alliances in Europe (Industrie 4.0) and North America (Industrial Internet Consortium). Though solving these challenges is not trivial, the prognosis for progress is good—which suggests the need for manufacturing executives to monitor the evolution of this new productivity lever.

Figure 11: IoT Value Creation Evolution



Source: A.T. Kearney

Changing Workforce Dynamics

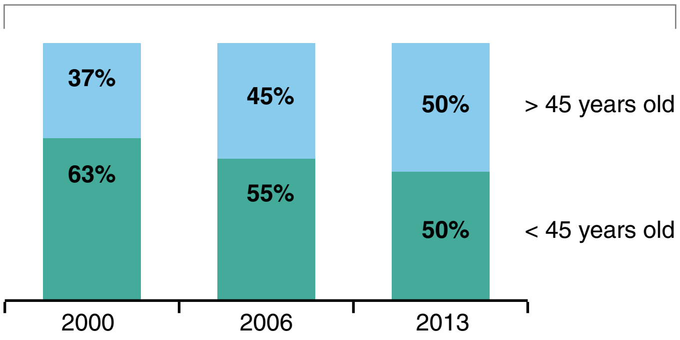
The replacement of existing infrastructure with smart manufacturing ecosystems will lead to a ripple effect creating indirect jobs in markets that supply, support and service these operating environments.

Addressing the Talent Gap

With most machines being computer controlled, today's manufacturing processes and equipment have become quite sophisticated. As production complexity continues to increase, manufacturers will need to find and/or develop the skills required to operate and maintain the machinery. These new skills are not completely unrelated to the old skill sets of manufacturing workers but rather are built on top of their skill foundation. However, a conflict arises when the talent pool shrinks or ages, as there are few skilled workers left to develop the new skills required.

The age profile of US manufacturing workers had an all-time-high median age of 45 years old in 2013 (see Figure 12), compared to 40 years old in 2000. Worsening the problem is the fact that about 10 percent of the current manufacturing workforce will retire in the next 3 to 5 years, and there isn't a significant number of quality replacement workers coming in. This skill gap is highlighted by the recent postings of over half a million unfilled manufacturing jobs in the US.

Figure 12: Aging of Manufacturing Workers



Data Source: Bureau of Labor Statistics
Analysis: A.T. Kearney

These trends threaten a serious loss in the operational expertise of workers, as the skill sets needed in the manufacturing industry mainly reside with experienced workers. Unfortunately, their expertise typically has not been codified and is therefore at risk of being lost upon their retirement.

A strong and renewed skills base will be central to strengthening the US manufacturing base in the future. This points to the importance of systematically identifying processes that are heavily reliant on expertise and codifying them into standard operating procedures, documented process recipes, and fully established apprenticeship models, before they are lost. The renewal of manufacturing skills will need to be built on the current skills foundation and will need to include the practical application of programming, simulation and statistical modeling among other fields.

Not only will U.S. manufacturers have to stem the rapid loss of essential knowledge that is not easily replicated or replaced, they will also need to step up recruiting and training of new workers to manage and carry out manufacturing activities. As they ramp up their recruiting efforts, they will find themselves competing with other sectors that may be more appealing to new job seekers. Younger workers often see other sectors as more attractive, even when they pay less than manufacturing, because they appear to have more comfortable working conditions and to require fewer technical skills.

New Indirect Roles Created

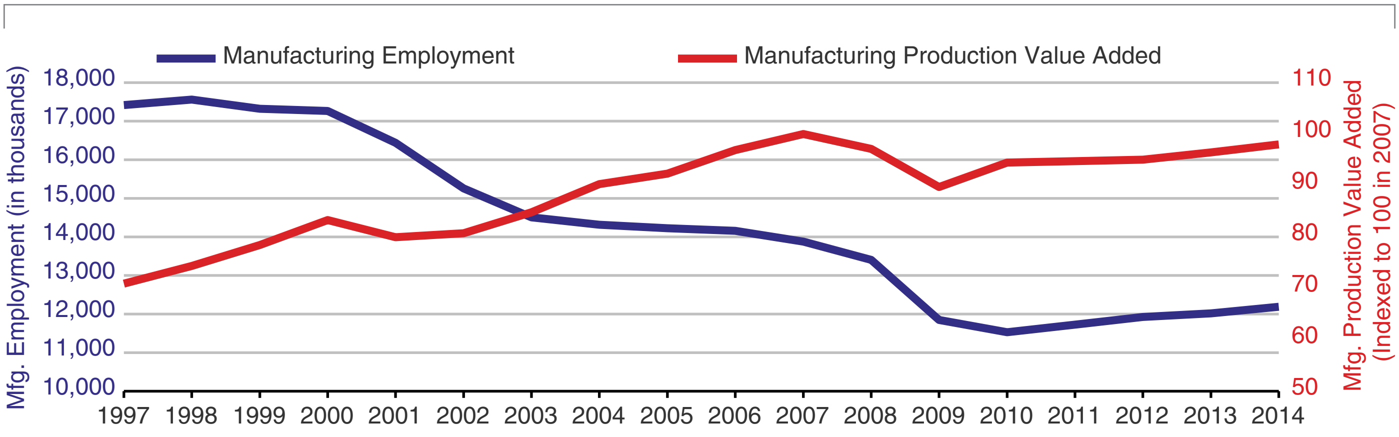
The last three decades have seen a steady decline in the number of direct manufacturing jobs, yet direct labor productivity levels have never been so high (see Figure 13).

At a first glance, one might think that all manufacturing jobs are effectively driven away by more productive ways of manufacturing (automation, etc.). However, these lost roles of the past are giving way to new positions in the extended supply chain.

Traditional, direct manufacturing jobs typically included very manual tasks performed by humans, for example, setting up equipment, loading material, operating machines, and moving materials from one work station to the next. As manufacturing has become more automated and complex, robots and machines now perform many of these tasks and the human-performed tasks are shifting to higher value-added activities such as optimizing the plant layout, programming robots and machines to perform tasks, and monitoring performance to identify parameter excursions.

These new roles are found in the extended supply chain as manufacturing companies leverage many other indirect jobs and suppliers (tier 1, tier 2, tier 3 suppliers; logistics; banking; etc.) and are connected in real time, effectively creating smart manufacturing ecosystems.

Figure 13: US Manufacturing Direct Jobs vs. Output



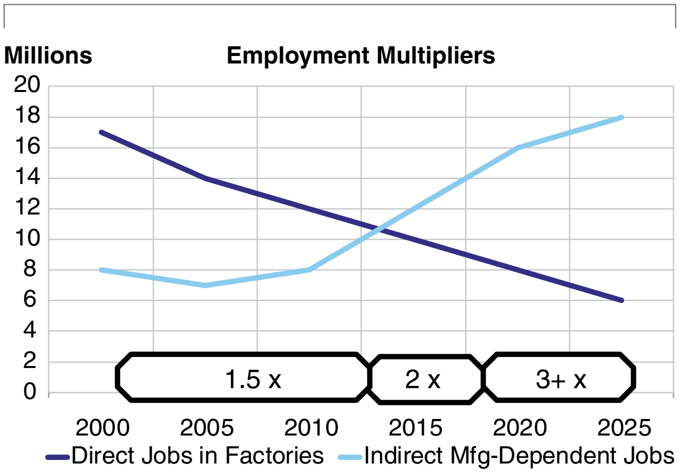
Data Source: Bureau of Labor Statistics and Bureau of Economic Analysis
Analysis: A.T. Kearney

This leverage of indirect jobs results in a job multiplier effect. According to the National Association of Manufacturers, the manufacturing employment multiplier is 1.58 on average (see Figure 14), but smart manufacturing environments are known to raise the employment multiplier to 2.0 or even higher. (A study of the workforce related to Intel in Oregon showed a ratio as high as 4.1.)[11]

The implementation of new smart manufacturing ecosystems will indirectly create high-skilled professional jobs with higher salaries in adjacent/supplementary industries that are different from the manufacturing sector but directly related to it. The skills required for these indirect jobs will also evolve. For example, due to the dynamic nature of the technology behind smart manufacturing environments, there will be a strong demand for workers with a background in data analytics, simulation, and programming.

With this transformation of direct to indirect jobs comes a shift in the role of the traditional manufacturing plant: it evolves from being a central employment hub for workers to becoming the nucleus of a larger network which employs people in a range of other industries that provide supply, support, and services to the manufacturing operation.

Figure 14: Direct vs. Indirect Manufacturing Jobs



Data Source: National Association of Manufacturers
Analysis: John A. Bernaden, SmartManufacturing.com

Implications of the Manufacturing Revolution

The many forces of change highlighted above are fueling each other as they evolve and transform the manufacturing landscape.

And while the key drivers of change will affect all sectors, some industries will be disrupted more than others. A.T. Kearney evaluated groupings of the NAICS industry sectors to understand the current state and potential impact of the five forces discussed in the previous sections. The results of this evaluation are shown in Figure 15 using an impact scale of 0 to 4, where 0 means no impact and 4 means high impact.

This assessment suggests that three manufacturing sectors have the potential to be most impacted by these five forces of change, suggesting particular opportunities (and threats).

Computer, Electronics & Electrical Products: This sector is expected to see the biggest impact as it both satisfies and enables innovation-driven shifts in consumer expectations. Manufacturers will have the opportunity to produce in local markets more cost-effectively as automation and 3D printing enable lower-cost, highly-customized manufacturing. Simultaneously, IoT will connect consumers to manufacturers throughout the entire product life cycle, providing manufacturers with detailed information about consumer patterns, but also obligating manufacturers to deliver a higher level of quality and service. With the increased presence of these information technologies, a high-skilled workforce will be required to fuel the growth and transformation of this sector.

Transportation Vehicles & Equipment: A more customer-centric value proposition from the industry will mean more interaction and expectation from end users. This sector will also continue to change its manufacturing footprint as it addresses the need to be closer to its markets and leverages new sources of productivity including automation and IoT. Companies such as Tesla Motors and Local

Motors are already providing proof points for highly-customized, regionally-produced products.

Apparel & Textiles: The apparel industry is highly consumer driven and often volatile, with short product life cycles that require fast delivery and tight control over production and inventory. Particularly at the industry's higher end, the past value chain strategy of using low-cost countries for production will give way to more localized and integrated production that leverages IoT to sense consumer demand, engages automation to efficiently personalize products, and uses 3D printing to produce integral, personalized apparel and accessories on demand.

Figure 15: Evaluation of Impact of Forces of Change on NAICS Industry Sectors

	Selected Forces of Change					
Sectors	**Shifting Consumer Requirements**	**Globalization**	**Technological Advances**	**New Productivity Levers**	**Changing Workforce Dynamics**	**Total**
Minerals	◔	◔	◑	◔	◑	◔
Fabricated Metals & Machinery	◔	◕	◕	◕	◑	◑
Computers, Electronics & Electrical Products	●	●	●	●	●	●
Transportation Vehicles & Equipment	◕	●	●	●	●	●
Furniture	◑	◑	◕	◕	◑	◑
Food, Beverages & Tobacco	◕	◔	◕	◕	◑	◑
Textiles & Apparel	●	◕	◑	◕	◑	◕
Paper & Printing	◕	◑	◑	◑	◔	◑
Petroleum, Chemicals & Plastics	◔	◔	◑	◑	◕	◑

○ **No Impact** ● **High Impact**

Note: Using the NAICS industry categorization, nine industry groupings were created based on the similarity of resources used, markets reached and their operating characteristics. They add up to 97% of manufacturing output.

Source: Bureau of Labor Statistics

Analysis: A.T. Kearney

INSIGHT

The Third Era of Design: Connection

Diego Tamburini, Autodesk, Inc.

In the early 1980s, the design process underwent a major evolution when computer-aided design (CAD) went mainstream and 2D drawings moved from paper to the computer. While this was, without a doubt, a radical step for design, CAD was basically being used as a fancy replacement for pen and paper to document the design (although in a much more accurate and efficient way, of course). This period is called the *"Era of Documentation."*

As design software evolved from 2D to 3D, the Era of Documentation slowly gave way to the *"Era of Optimization."* This era is all about creating rich 3D models and using them to visualize, simulate and optimize a design before the first prototype is built. We are at the tail end of this era now.

We are now entering a new era of product development; one characterized by complex, multi-disciplinary, interconnected systems. This period can be called the *"Era of Connection."*

In the Era of Connection, no product is an island anymore. Instead, products are nodes in a larger network of interconnected systems—a network that includes not only other products, but also the operational environment, the customers who use them, the resources that manufacture them, the designers who design them, the organizations that maintain them, the rules that regulate their behavior, the business objectives of the company that makes them, and more.

In this era, the goal is to optimize for the entire *system*, not just the individual product in isolation. While in the Era of Optimization we wanted to make sure that the *design worked right*, in the Era of Connection we want to make sure that we have the *right design.*

The products at the center of it all are being radically transformed. Most "things" designed today are getting an IP address and can connect with and be addressed by other things, and they participate in a wide range of unprecedented multi-device scenarios. Inside these products things have changed too: the lines between software, hardware and electronics are blurring and becoming virtually indistinguishable. Electronics and software are not just supporting the hardware anymore; they are the product too. This requires a design mindset (and tools) that are different from those involved when various portions of the product are developed in "disciplinary silos" and somehow forcibly integrated down the line in the product development process. The Era of Connection requires designing with connectivity in mind from the start, with a more seamless integration between hardware, software and electronics design.

The expectations customers have for products are also changing. Customers are increasingly expecting products to be extended and upgraded: extended by third parties who can use the products' APIs to develop applications or services on top of the products (just as developers do today for PCs and mobile devices), and improved with over-the-wire software upgrades that make the hardware perform better.

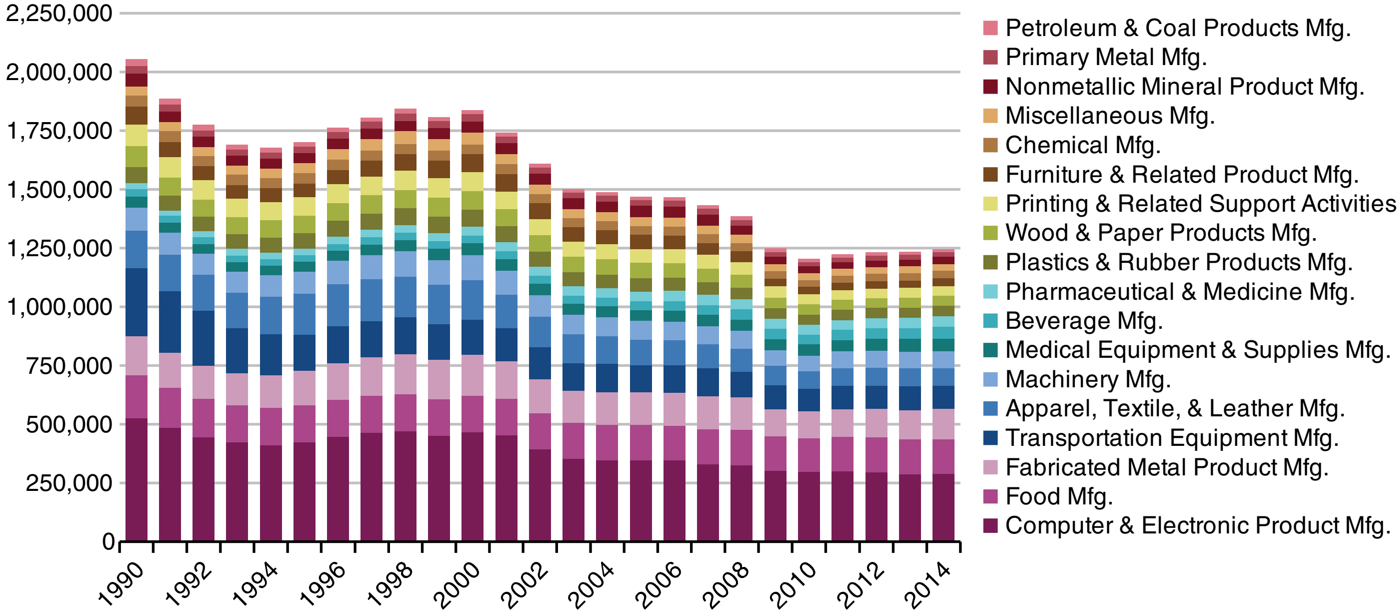
Disrupting the way things are designed and made, the Era of Connection puts an even bigger burden on design software solutions: to build applications and solutions that not only utilize rich 3D models, but also connect them to new means of production and consumption and support the new definition of what a product is.

California's Shifting Landscape: Manufacturing and the Innovation Ecosystem

People often don't realize that California has more manufacturing jobs than any other state in the US. As of March 2015, employment in manufacturing sectors totaled 1,271,672 in California, representing 9.3 percent of the state's total employment.[12]

California's producers are diverse, are geographically distributed across the state, and include many small and medium-sized manufacturers. Many work hand-in-hand with tech companies, prototyping designs and producing specialized components and advanced end products.

California Manufacturing Employment by Sector, 1990–2014



Note: For the California manufacturing analyses presented herein, the definition of the Chemical Manufacturing sector used throughout excludes Pharmaceutical & Medicine Manufacturing, which is analyzed and listed as a separate sector.

Data Source: Quarterly Census of Employment & Wages, California EDD

Analysis: Bay Area Council Economic Institute

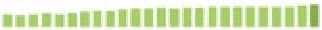
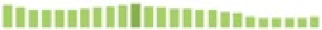
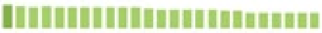
California is also home to some of the world's largest technology companies that offer the products and services for advancing any production process. The state's research organizations are pushing the envelope in advancing materials science, process design, manufacturing tools and technology. California's innovation ecosystem is rich in resources that are relevant for manufacturers.

Many of California's manufacturers are closely integrated into the state's innovation ecosystem. Better leveraging of California's distinctive innovation assets for the benefit of its manufacturers can reach beyond the state's borders, as many manufacturers are tied with affiliated producers in other states.

Growth Trends

In examining trends in California's manufacturing employment and establishments, two time periods are highlighted in this report. Long-term trends, 1990–2014, reflect structural change in the economy, namely the long-term impacts of globalization, technological advance and overall restructuring of production. The recent period of observation, 2010–2014, illustrates manufacturing growth since the low point of the last recession. This period has witnessed the rising cost of labor in China, growing concerns about intellectual property and quality control associated with overseas production, historically low interest rates, and the quickening development and adoption of new technology that allows for a more distributed model of production.

California Manufacturing Employment Change by Sector, 1990–2014

	Employment					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Beverage Mfg.	34,132	41,740	50,035	46.6%	19.9%	
Fabricated Metal Product Mfg.	168,420	114,421	128,808	-23.5%	12.6%	
Machinery Mfg.	99,366	65,389	71,897	-27.6%	10.0%	
Pharmaceutical & Medicine Mfg.	25,508	42,960	46,877	83.8%	9.1%	
Medical Equipment & Supplies Mfg.	45,163	49,423	53,922	19.4%	9.1%	
Furniture & Related Product Mfg.	75,331	30,844	33,562	-55.4%	8.8%	
Nonmetallic Mineral Product Mfg.	55,603	28,516	29,928	-46.2%	5.0%	
Miscellaneous Mfg.	40,108	28,759	30,164	-24.8%	4.9%	
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	47,046	29,810	30,943	-34.2%	3.8%	
Food Mfg.	183,116	144,486	149,277	-18.5%	3.3%	
Total California Mfg.	**2,053,550**	**1,205,664**	**1,243,329**	**-39.5%**	**3.1%**	
Apparel, Textile, & Leather Mfg.	157,949	72,826	74,466	-52.9%	2.3%	
Transportation Equipment Mfg.	289,501	97,081	97,988	-66.2%	0.9%	
Wood & Paper Products Mfg.	91,097	42,155	42,358	-53.5%	0.5%	
Plastics & Rubber Products Mfg.	66,623	43,122	43,206	-35.1%	0.2%	
Primary Metal Mfg.	31,956	18,669	18,462	-42.2%	-1.1%	
Computer & Electronic Product Mfg.	523,865	295,532	287,545	-45.1%	-2.7%	
Printing & Related Support Activities	91,187	44,770	41,758	-54.2%	-6.7%	
Petroleum & Coal Products Mfg.	27,579	15,161	12,133	-56.0%	-20.0%	

Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

As a result of globalization and other changes in the production process, manufacturing in California as a whole has seen overall declines similar to national trends since 1990. Manufacturing employment in California today is 39.5 percent below 1990 levels.

However, manufacturing is a highly diverse part of the economy, and three manufacturing sectors have seen steady job growth in the state over the long term (1990–2014): Pharmaceutical & Medicine Manufacturing gained 21,369 jobs in the state, Beverage Manufacturing gained 15,903 jobs, and Medical Equipment & Supplies Manufacturing added 8,759 jobs.

Following a trend similar to employment, the number of manufacturing establishments increased in the late 1990s and then steadily declined until 2013. Also similar to long-term employment trends, in 2014 there were 23.9 percent fewer manufacturing establishments in California than in 1990.

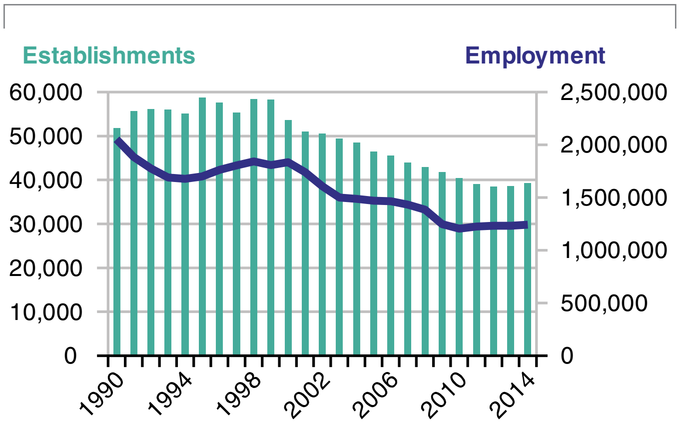
In the recent time period (2010–2014), manufacturing employment has grown, although not as fast as employment overall. Between 2010 and 2014, total manufacturing employment expanded by 3.1 percent in the state. (Total state employment grew by 9.2 percent.) Employment gains were seen in 14 of 18 manufacturing sectors.

California Manufacturing Establishment Change by Sector, 1990–2014

	Establishments					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Beverage Mfg.	691	1,354	1,870	170.6%	38.1%	
Food Mfg.	3,557	3,351	3,601	1.2%	7.5%	
Petroleum & Coal Products Mfg.	246	220	228	-7.3%	3.6%	
Machinery Mfg.	3,470	2,627	2,663	-23.3%	1.4%	
Computer & Electronic Product Mfg.	5,730	4,608	4,640	-19.0%	0.7%	
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	1,191	1,216	1,216	2.1%	0.0%	
Medical Equipment & Supplies Mfg.	1,928	1,657	1,638	-15.0%	-1.1%	
Total California Mfg.	**51,767**	**40,532**	**39,389**	**-23.9%**	**-2.8%**	
Pharmaceutical & Medicine Mfg.	264	438	424	60.6%	-3.2%	
Fabricated Metal Product Mfg.	7,698	6,341	6,126	-20.4%	-3.4%	
Miscellaneous Mfg.	2,191	2,176	2,096	-4.3%	-3.7%	
Plastics & Rubber Products Mfg.	1,751	1,258	1,192	-31.9%	-5.2%	
Transportation Equipment Mfg.	2,074	1,612	1,519	-26.8%	-5.8%	
Wood & Paper Products Mfg.	1,987	1,484	1,379	-30.6%	-7.1%	
Printing & Related Support Activities	6,480	3,557	3,263	-49.6%	-8.3%	
Nonmetallic Mineral Product Mfg.	1,512	1,302	1,164	-23.0%	-10.6%	
Apparel, Textile, & Leather Mfg.	6,598	4,456	3,922	-40.6%	-12.0%	
Primary Metal Mfg.	656	578	501	-23.6%	-13.3%	
Furniture & Related Product Mfg.	3,743	2,297	1,947	-48.0%	-15.2%	

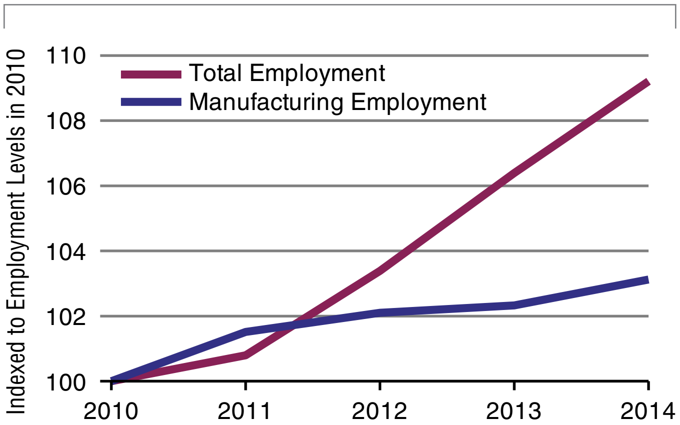
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Manufacturing Establishments & Employment in California, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Total vs. Manufacturing Employment Growth in California, 2010–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Growth in the Recent Time Period, 2010–2014

Since hitting a low in 2010, overall employment in California has grown 9.2 percent through 2014. Manufacturing employment as a whole expanded 3.1 percent over the same period, with a significant number of sectors showing promising gains. Between 2010 and 2014, the following five manufacturing sectors met or exceeded California's overall rate of growth:

Beverage Manufacturing, +19.9 percent, +8,295 jobs

Pharmaceutical & Medicine Manufacturing, +9.1 percent, +3,917 jobs

Medical Equipment & Supplies Manufacturing, +9.1 percent, +4,499 jobs

Fabricated Metal Manufacturing, +12.6 percent, +14,387 jobs

Machinery Manufacturing, +10.0 percent, +6,508 jobs

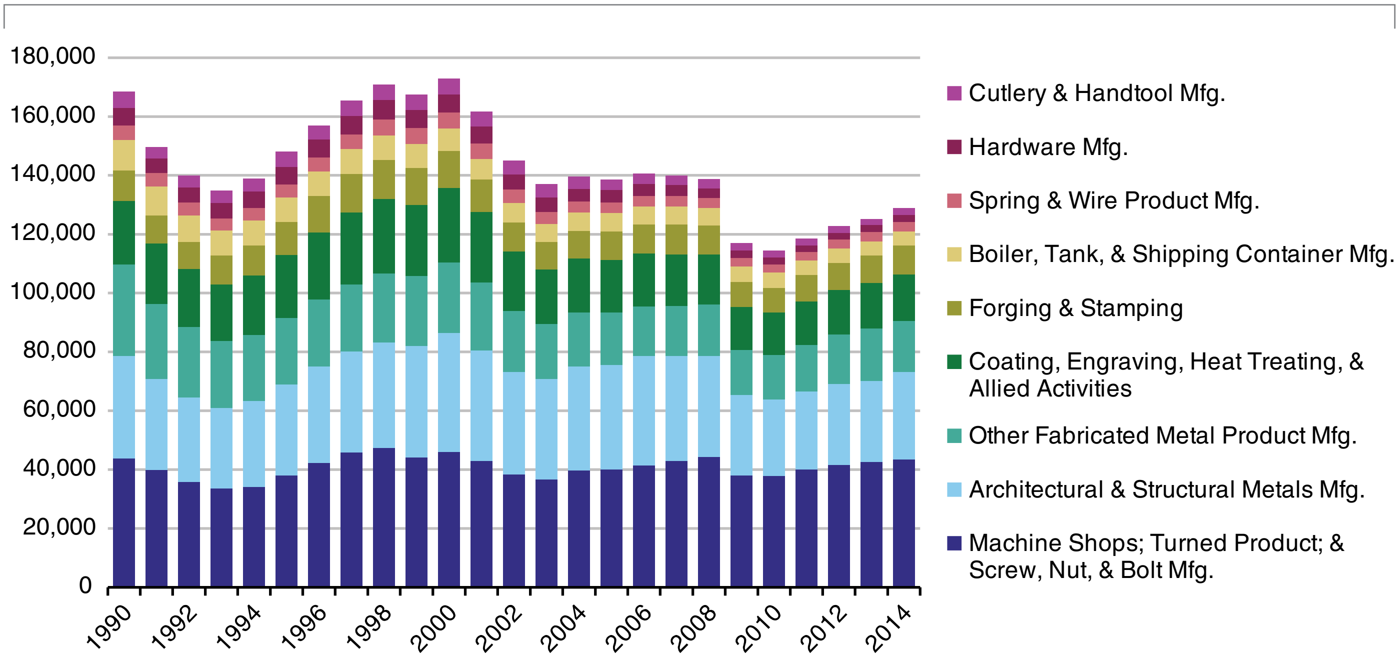
Of those five sectors, the growth in the first three (Beverage Manufacturing, Pharmaceutical & Medicine Manufacturing, and Medical Equipment & Supplies Manufacturing) also represents long-term (1990–2014) job gains in California. By contrast, the other two sectors (Fabricated Metal Manufacturing and Machinery Manufacturing) experienced long-term job losses between 1990 and 2014, and the jobs added since 2010 are a start at recovery from those losses.

In terms of employment, within **Fabricated Metal Manufacturing**, Machine Shops constituted the largest subsector with 43,544 jobs in 2014. Machine Shops also accounted for nearly 40 percent of the sector's recent employment growth, having gained 5,572 jobs between 2010 and 2014, and this subsector's 2014 employment level was its highest since 2008.

In terms of establishments, only one subsector within Fabricated Metal Manufacturing witnessed growth in the number of firms since 2010: Spring & Wire Product Manufacturing.

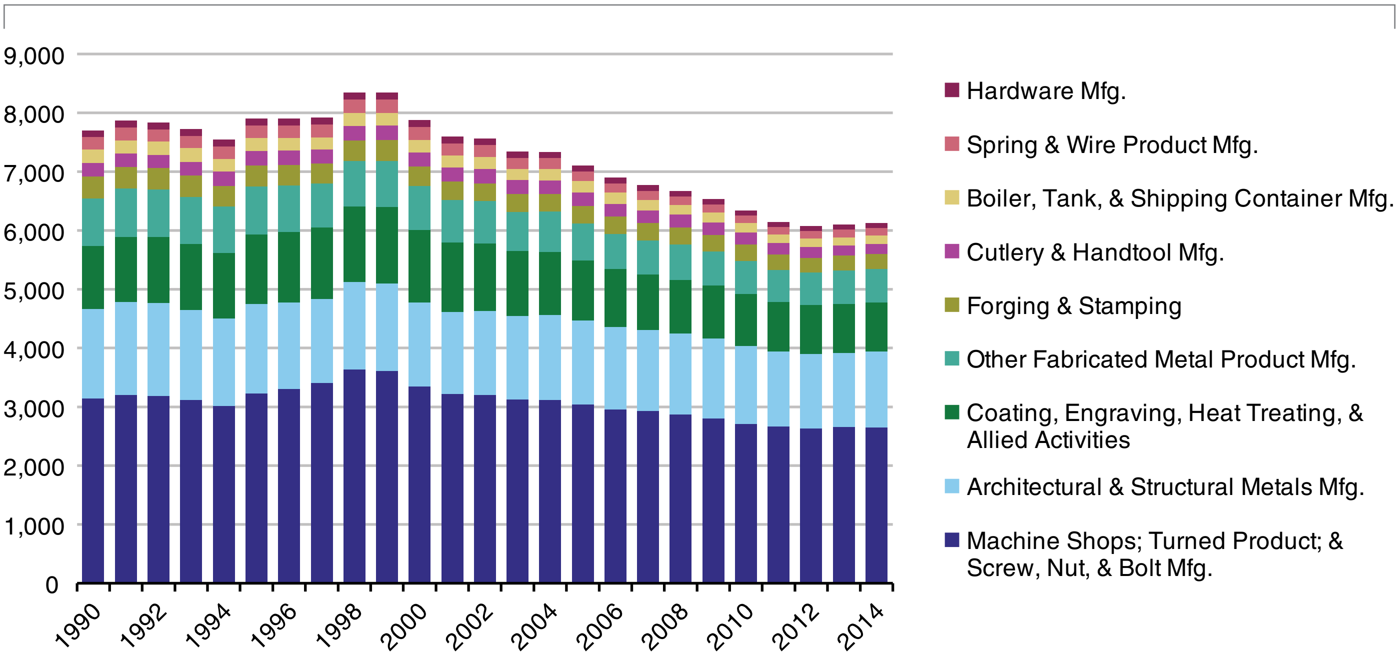
With over 70,000 jobs in 2014, **Machinery Manufacturing** accounted for 5.8 percent of California's manufacturing employment. In 2014, the two largest subsectors— Industrial Machinery Manufacturing and Other General Purpose Machinery Manufacturing—together accounted for 42.2 percent of Machinery Manufacturing sector employment, with 30,349 jobs, and 40.3 percent of Machinery Manufacturing sector establishments, with 1,074 establishments.

California Fabricated Metal Manufacturing Employment, 1990–2014



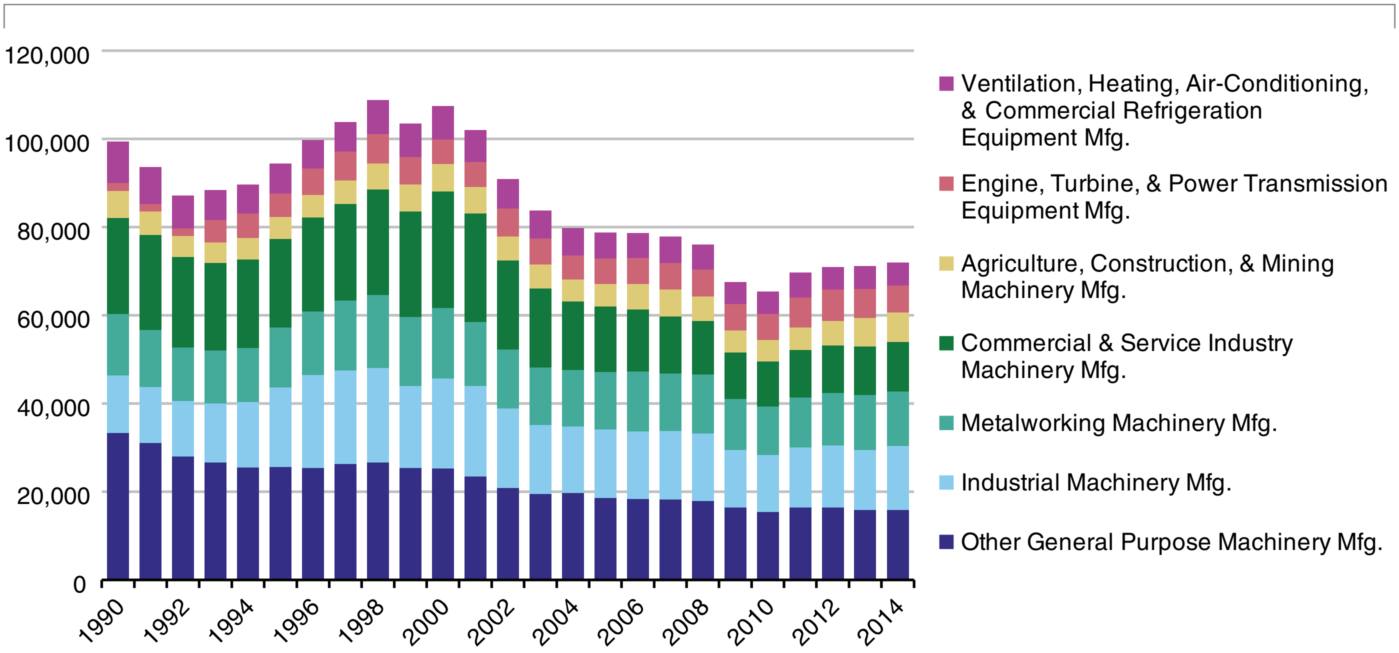
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

California Fabricated Metal Manufacturing Establishments, 1990–2014



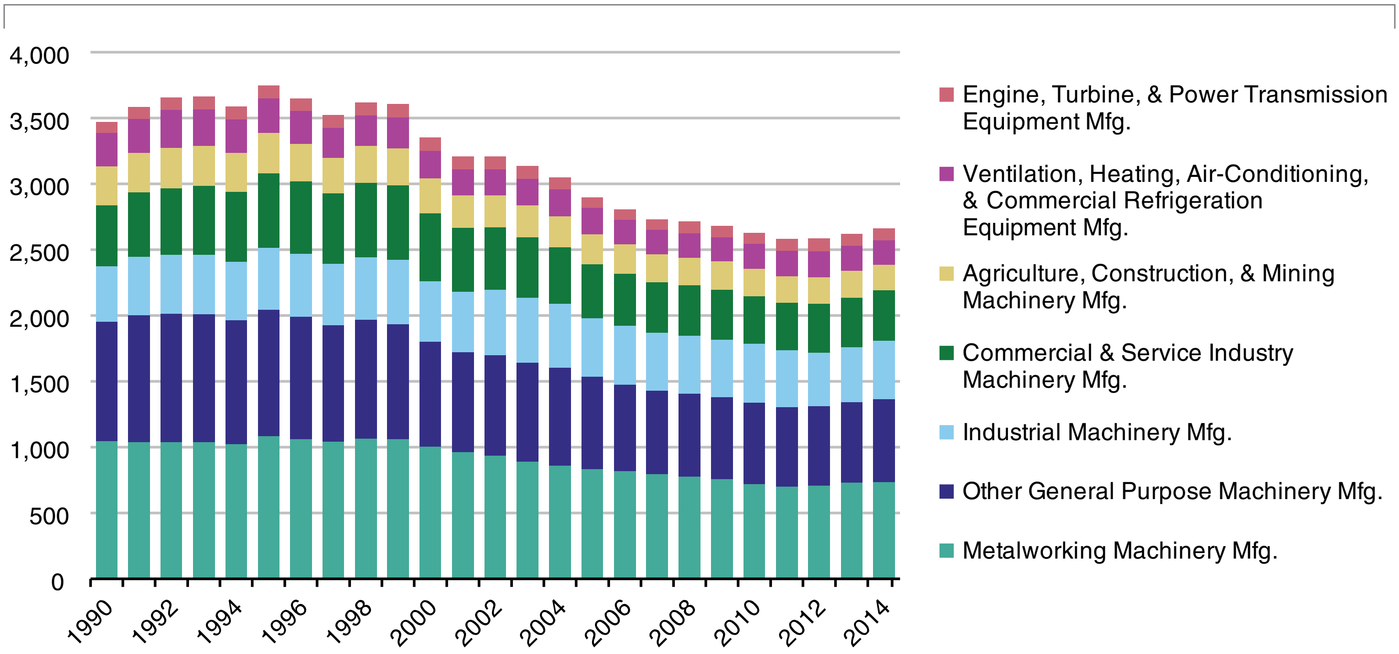
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

California Machinery Manufacturing Employment, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

California Machinery Manufacturing Establishments, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Growth in the Long Term, 1990–2014

Since 1990, **Pharmaceutical & Medicine Manufacturing** has witnessed the strongest employment growth of any manufacturing sector in California. From 1990 to 2014, jobs expanded by 83.8 percent, while the state's total manufacturing employment declined by 39.5 percent.

Within this sector, the Pharmaceutical Preparation subsector accounted for the largest employment share with 33,482 jobs in 2014 and 71.4 percent of Pharmaceutical & Medicine Manufacturing employment in California. Between 1990 and 2014, Pharmaceutical Preparation jobs expanded by 85.5 percent. During the same period, employment grew by 203.0 percent in In-Vitro Diagnostic Substance Manufacturing (with a net gain of 4,164 jobs) and 130.4 percent in Medicinal & Botanical Manufacturing (with a net gain of 2,497 jobs). Only Biological Product Manufacturing experienced job losses, with employment declining by 20.7 percent since 1990. (In comparison, all four subsectors experienced growth in the recent time period from 2010–2014, with Medicinal & Botanical Manufacturing showing the most significant gains, expanding by 88.9 percent.)

In terms of establishment growth, Pharmaceutical & Medicine Manufacturing firms increased in number by 60.6 percent between 1990 and 2014. Pharmaceutical Preparation was responsible for 70.0 percent of this growth, expanding by 89.6 percent and adding 112 establishments. The number of firms in Medicinal & Botanical Manufacturing reached an all-time high in 2014, expanding by 115.4 percent between 1990 and 2014 to a total of 84 manufacturing establishments.

Second only to Pharmaceutical & Medical Manufacturing, California's employment in **Beverage Manufacturing** increased by 46.6 percent in the long term, 1990–2014. Wineries drove much of that job growth within the sector, expanding by 121.3 percent between 1990 and 2014. Employment in Breweries was robust, expanding by 43.8 percent over the 1990–2014 period.

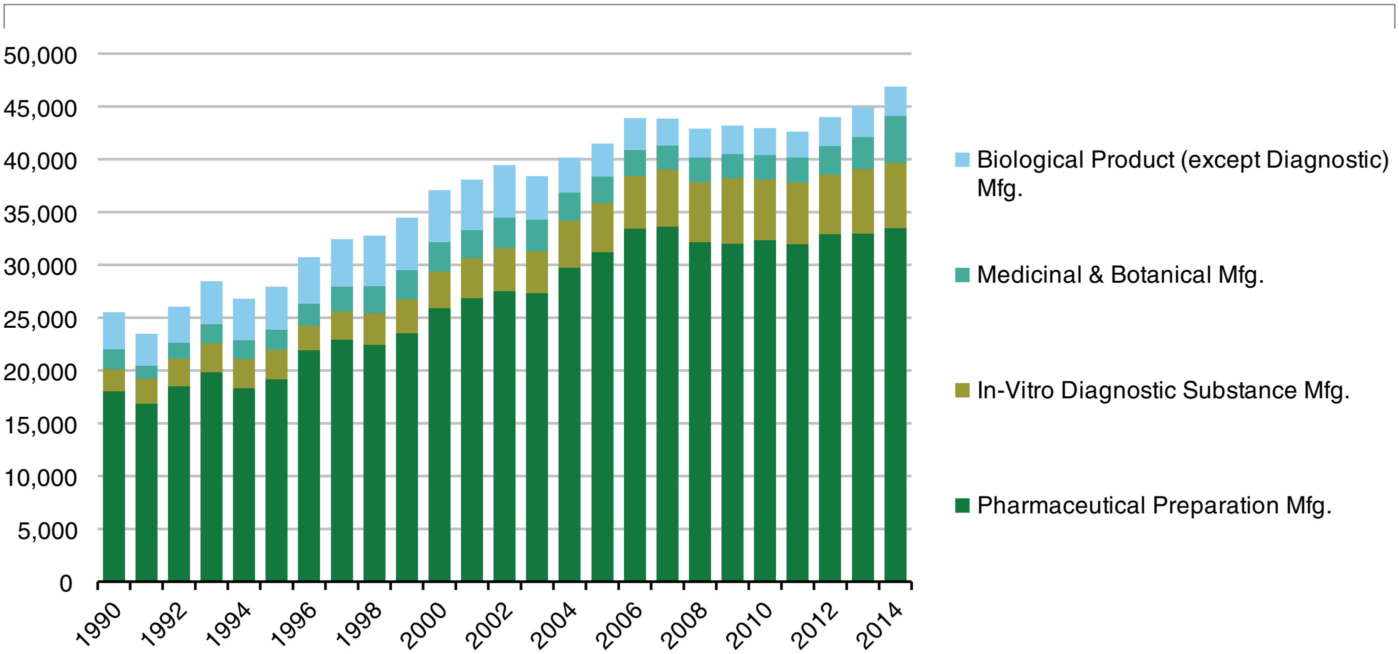
The Wineries, Breweries and Soft Drink & Ice Manufacturing subsectors together saw establishment growth between 1990 and 2014, and all three subsectors experienced significant establishment growth since 2010.

Though still a relatively small share of overall establishments in Beverage Manufacturing, the number of Breweries grew from 22 in 1990 to 169 in 2014, with the fastest growth occurring since 2010 with an increase from 37 establishments to the 169 total.

Since 1990, employment in **Medical Equipment & Supplies Manufacturing** increased by 19.4 percent, peaking in 2014 with 53,922 jobs. This growth was driven by the Surgical & Medical Instrument Manufacturing subsector, which expanded by 61.9 percent, with a net gain of 9,852 jobs between 1990 and 2014. Dental Laboratories were not far behind however, expanding by 57.7 percent with a net gain of 3,098 jobs. In contrast, employment in two of the subsectors—Surgical Appliance & Supplies Manufacturing and Ophthalmic Goods Manufacturing—contracted by 6.8 and 33.4 percent respectively.

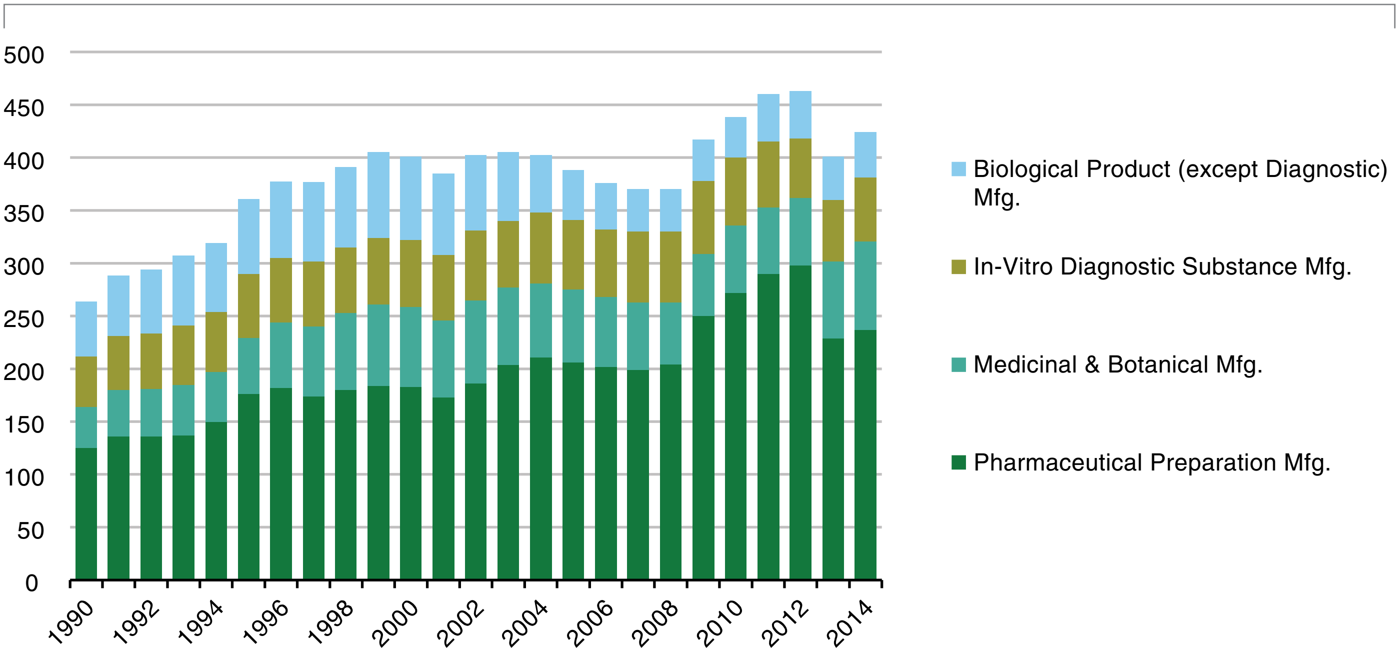
While Dental Laboratories made up 54.2 percent of the 1,638 establishments in Medical Equipment & Supplies Manufacturing in 2014, establishment growth in the sector since 1990 was driven by the Surgical & Medical Instrument Manufacturing subsector, which expanded by 13.8 percent between 1990 and 2014, with a net gain of 33 establishments. (The number of Dental Laboratory establishments contracted by 19.8 percent between 1990 and 2014.)

California Pharmaceutical & Medicine Manufacturing Employment, 1990–2014



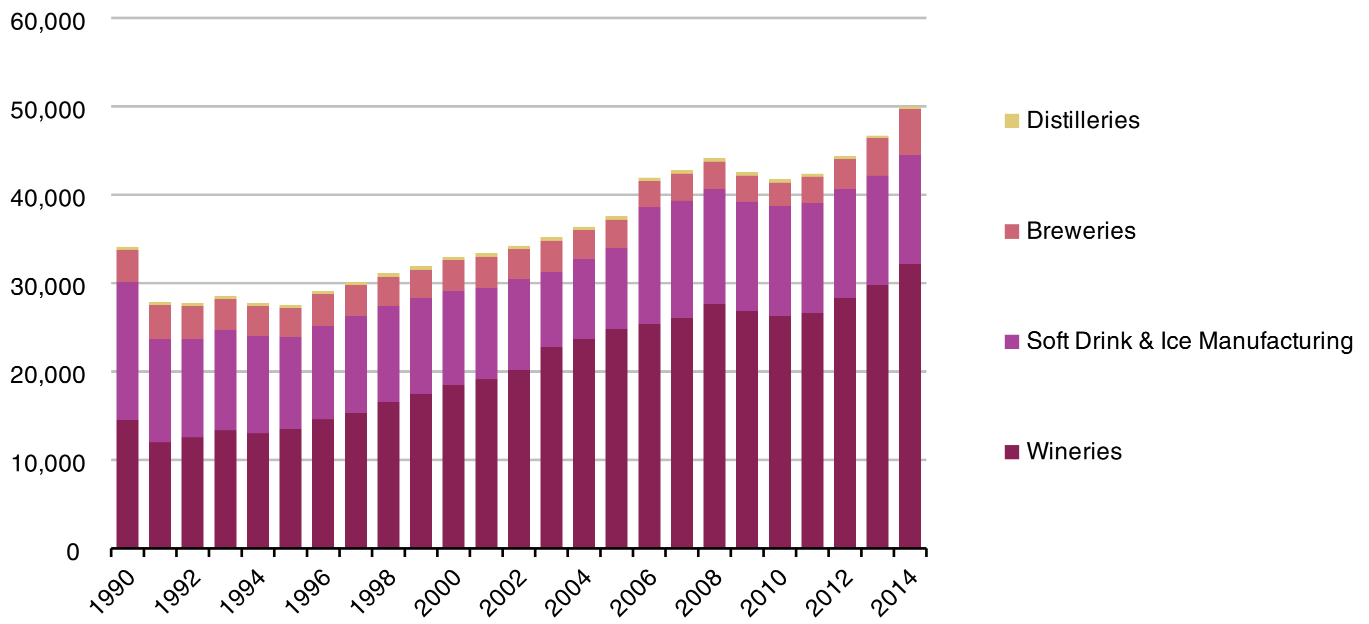
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

California Pharmaceutical & Medicine Manufacturing Establishments, 1990–2014



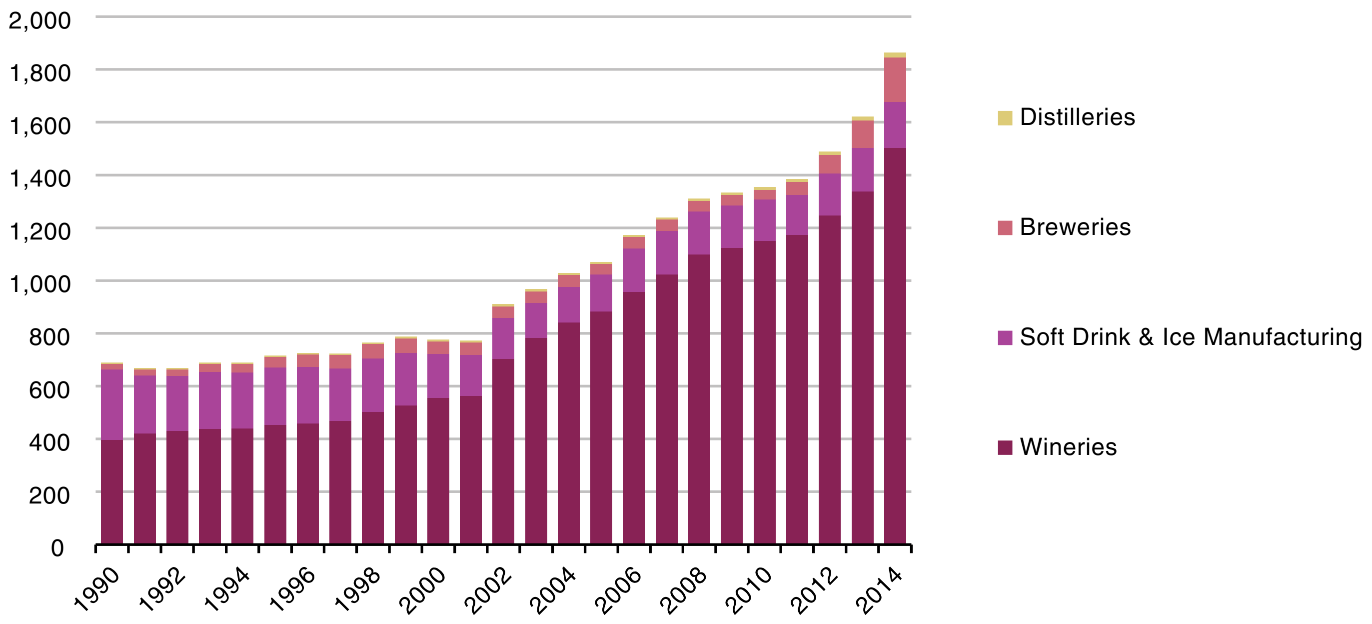
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

California Beverage Manufacturing Employment, 1990–2014



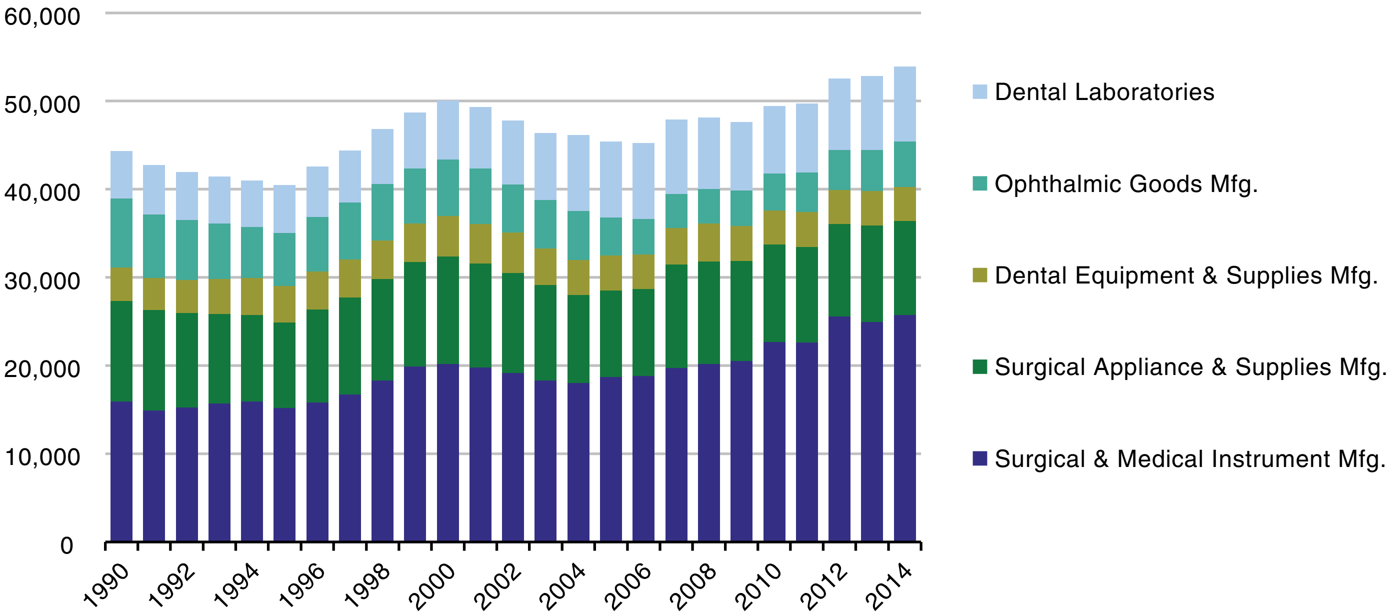
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

California Beverage Manufacturing Establishments, 1990–2014



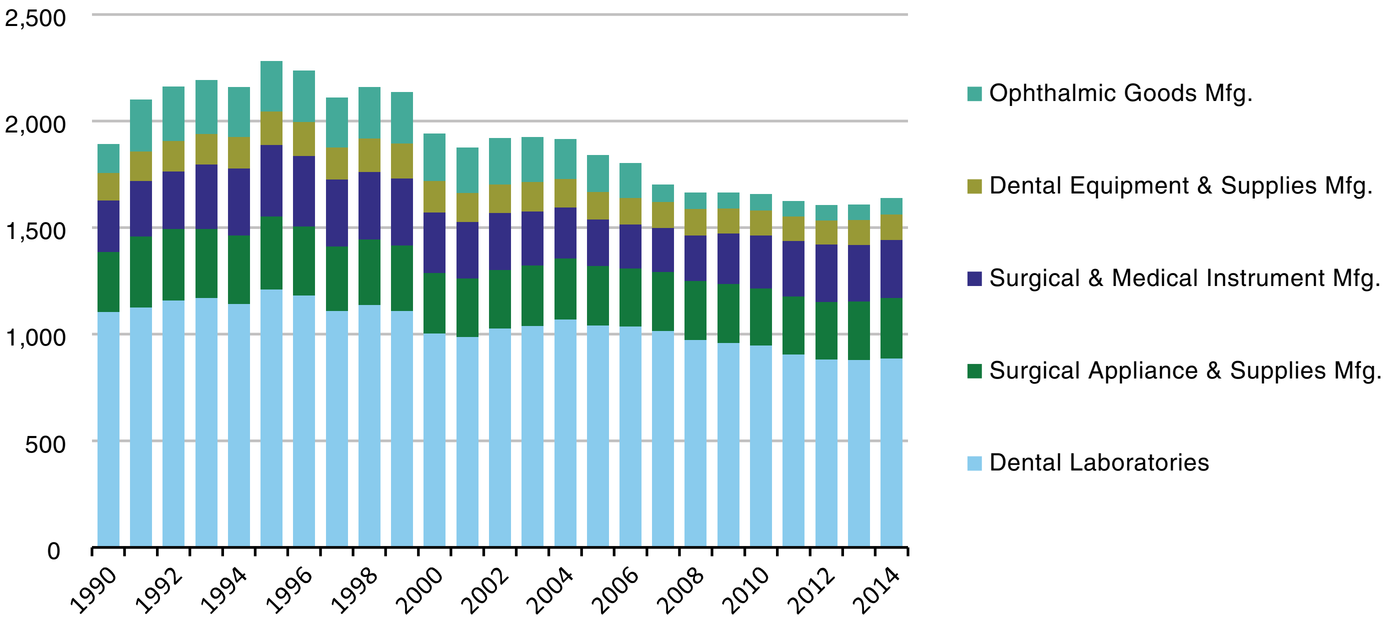
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

California Medical Equipment & Supplies Manufacturing Employment, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

California Medical Equipment & Supplies Manufacturing Establishments, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

California Manufacturing Highlights

Edwards Lifesciences

Irvine-based Edwards Lifesciences is the global leader in the science of heart valves and blood flow monitoring. More than 300,000 valve replacements are performed worldwide each year through open-heart surgery, utilizing either synthetic tissue valves or mechanical valves—many manufactured by Edwards Lifesciences.

Since its beginnings in Orange County more than 50 years ago, Edwards Lifesciences has grown into a global company with a presence in approximately 100 countries and 8,500 employees worldwide. Its domestic manufacturing locations include facilities in Irvine and in Draper, Utah. The company has several other global locations in the Dominican Republic, Puerto Rico, Singapore, and Switzerland.

DAQRI

Los Angeles-based startup DAQRI is applying its digital sensing and augmented reality products in industrial applications to improve training and quality control. DAQRI's "smart helmet"—which utilizes a transparent visor and special lenses that serve as a display, along with an array of cameras and sensors that help users navigate and gather information about their environment—is being used to empower manufacturing workers, oil rig employees, firefighters, and others with access to real-time metrics and instructions without the need for a tablet or monitor.

Cepheid

Sunnyvale-based Cepheid, a fast-growing medical diagnostic company with roots at UC Berkeley, develops products that can rapidly test for tuberculosis, socially transmitted diseases, influenza and specific types of cancer. With more than 1,700 employees, it manufactures in Sunnyvale, Lodi and Solna, Sweden. Production is expanding in Lodi, where the company plans to grow its workforce from 230 to approximately 500 in the next few years.

Finelite

Headquartered in Union City, Finelite focuses on the design and manufacture of high-performance, environmentally sustainable LED and fluorescent lighting systems for office, healthcare, and educational facilities. Its customers range from firms like Google, Verizon, and Dell, to universities such as MIT, Stanford, and Yale. Finelite's 182,000 square foot manufacturing facility is capable of assembling over 20,000 linear feet of lighting fixtures per day. Operating in California for 24 years, the company taps into technologies created in Silicon Valley and collaborates with the California Energy Commission to develop lighting products to meet new efficiency standards.

The company employs 270 people in Union City and has over 1,000 California employees spread across a metal fabricator operation in Los Angeles and a high-speed painting location in Livermore. Holding joint patents with the California Lighting Technology Center at the University of California, Davis, in 2011, Finelite created several application guides to show how to cut energy usage in half without compromising lighting quality—solutions that enhance productivity and move toward net zero energy use.

Keystone Engineering

Keystone Engineering was founded in 1907 as one of the first companies in Los Angeles to offer welding services. Today, the company employs 42 people and has evolved into a world leader in the design and fabrication of engineered products used in critical aerospace and defense applications. Keystone designs and produces lightweight propellant and pressure storage tanks, as well as unique fabrication and design technologies for propellant storage. These products are used in the International Space Station, satellites, suborbital unmanned aerial vehicles, and in other space and stratospheric explorations. With the expansion of its 57,000 square foot Long Beach facility, Keystone is growing to meet customer needs for the new generation of spacecraft.

Wing Inflatables

Since the early 1990s, Arcata-based Wing Inflatables has manufactured inflatable boats and watercraft sponsons for customers ranging from the U.S. military to commercial marine operations. (A sponson projects from the side of the boat to add greater stability to the watercraft.) Wing's flagship line is its Combat Rubber Raiding Crafts, inflatable rafts popular with the U.S. Department of Defense. These boats are used for Navy SEAL operations, Air Force water rescues, and Army beach landings. They are also used by the National Oceanic and Atmospheric Administration (NOAA) to rescue whales and by the National Air and Space Administration (NASA) to recover space capsules.

Today, Wing Inflatables is recognized as the premium quality fabricator of polyurethane inflatables in the world and has garnered more than $15 million in government contracts. Wing is also expanding its reach to Europe and Australia, and it has grown from 50 employees in July 2013 to more than 130 currently.

SPOTLIGHT

Tesla: Growing a Localized Supply Chain

In 2010, when General Motors and Toyota closed New United Motor Manufacturing Inc. (NUMMI), their automotive joint venture in Fremont, California lost its last remaining auto manufacturing plant. The closure not only resulted in job losses at those specific plants but also at the firms supplying NUMMI.

That same year, Tesla purchased the Fremont factory and now produces more than 35,000 electric vehicles per year there. The company has grown to 6,500 employees in California today, with the majority located at the Fremont factory. Tesla also houses workers in its corporate headquarters in Palo Alto, in a specialized production shop in Lathrop in the Central Valley, and at design studios outside of Los Angeles in Hawthorne.

As the company continues to grow—it has ambitions to produce 500,000 cars per year by 2020—it has made an effort to develop its supply chain close to the Fremont plant, even offering space to suppliers within the Tesla Fremont facility. As a result, a dynamic automotive supply chain has developed in the Bay Area—where previously many of these manufacturing activities had been thought to have left California forever.

For example, Futuris Automotive, which supplies Tesla interior components such as seats, operates out of a 160,000 square foot facility in Newark, just 15 minutes from Tesla's Fremont factory. Originally operating inside the automaker's Fremont plant, Futuris found a permanent home in Newark that can accommodate its growth. At full volume, Futuris plans to employ 300 people in its plant. Eighty percent of its products are manufactured locally for Tesla.

Futuris, which is Australia-based, is not the only Tesla supplier to locate nearby. Asteelflash, based in Fremont, creates motherboards for the car console systems. Eclipse Automation, also based in Fremont, supplies custom automated manufacturing equipment to Tesla.

The City of Fremont aims to attract more manufacturing jobs and companies through the creation of an innovation district around the new Warm Springs BART station, with Tesla as its major tenant. Plans call for the transformation of 850 acres near the existing factory with as many as 4,000 housing units and the potential to create 12,000 jobs in new commercial and industrial spaces.

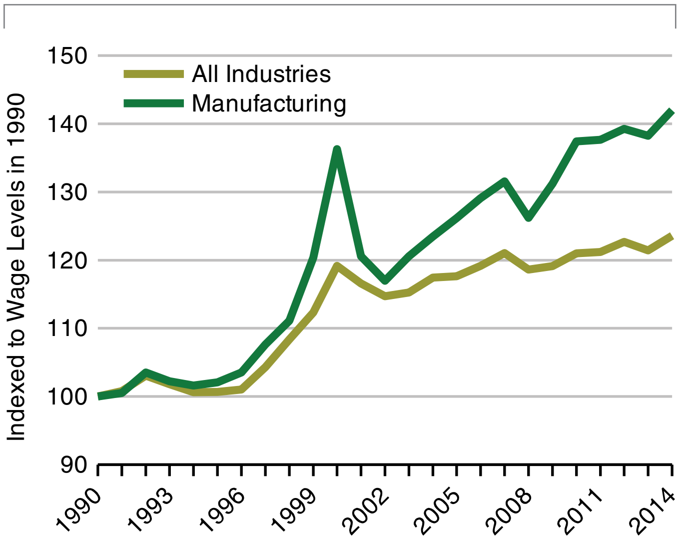
The ability for Tesla to procure parts for its cars locally not only reduces shipping costs and time, but also allows Tesla to work closely with suppliers to design products efficiently and to fix issues that may arise. This "near-shoring" of supply chains has become a key component in building localized industry clusters. Tesla's example shows that a large anchor manufacturing facility can attract other producers and drive the development of new clusters.

Manufacturing Wages in California

While total manufacturing employment in 2014 was 39.5 percent below where it was in 1990, inflation-adjusted average annual wages were 42.0 percent higher. Between 1990 and 2014, average annual incomes in manufacturing increased at a faster rate than the economy as a whole, where incomes rose by 23.6 percent. This suggests that the structural shifts that have taken place in manufacturing over the last several decades have resulted in the need for fewer but more highly qualified workers.

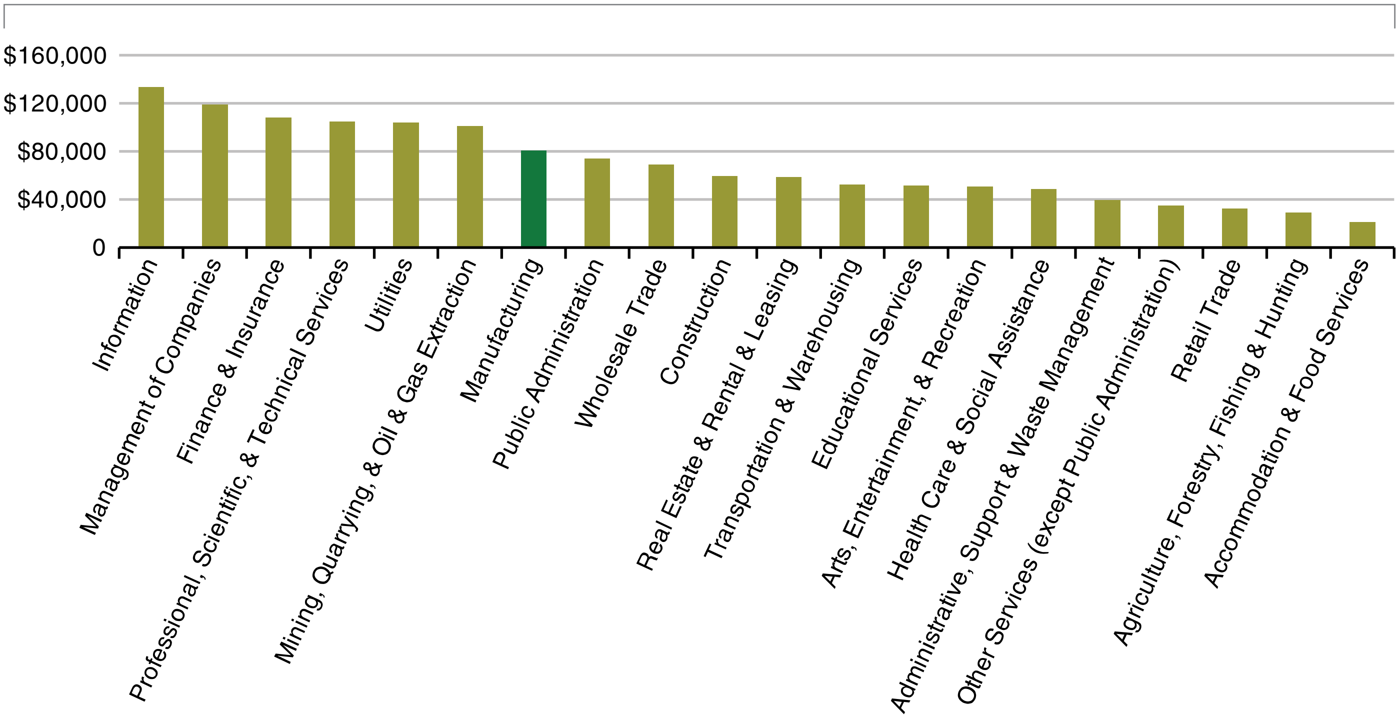
California's manufacturing jobs offer solid incomes. As a whole, average annual incomes of $80,000 were reported in manufacturing in 2014. With 2014 average annual incomes across the economy ranging from $20,000 in Accommodation & Food Services to $133,000 in Information, manufacturing jobs tend to fall at the upper end of the wage spectrum.

California Average Annual Earnings Trends
Total vs. Manufacturing Wages (Inflation Adjusted)



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

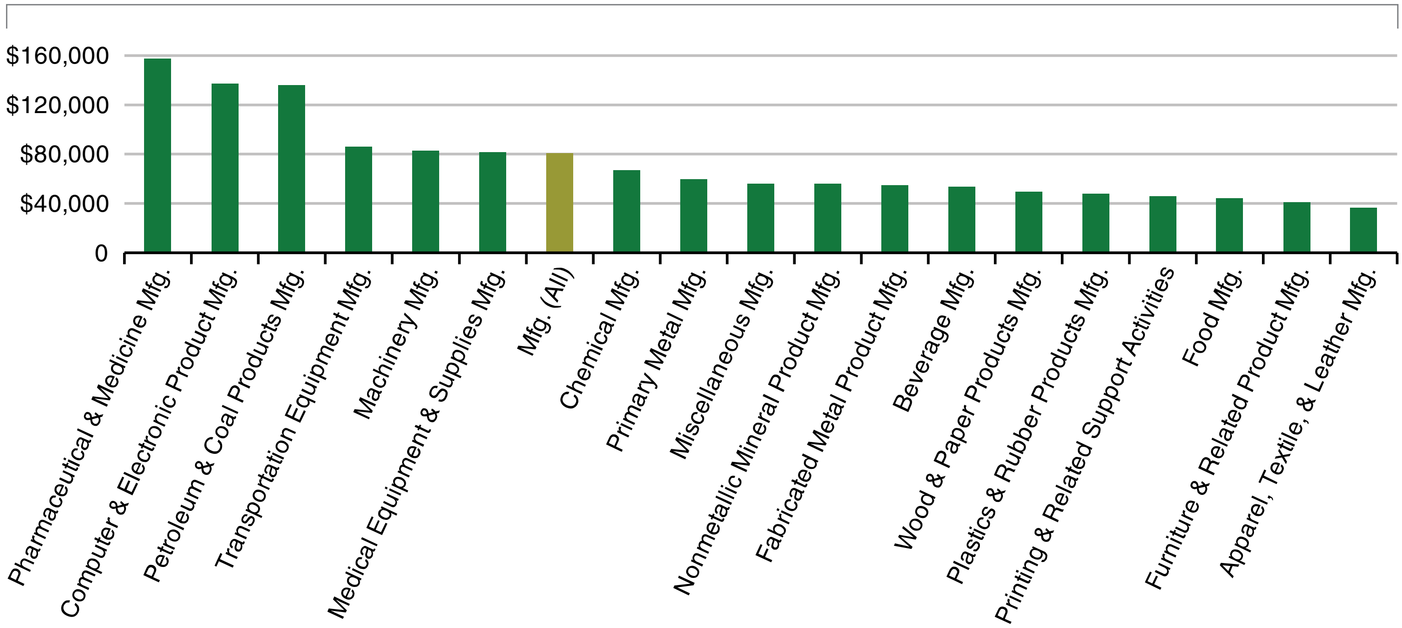
California Average Annual Earnings by Industry, 2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Within manufacturing, 2014 average annual incomes varied widely. At $157,000, Pharmaceutical & Medicine Manufacturing reported the highest average annual incomes. Computer & Electronic Product Manufacturing and Petroleum & Coal Products Manufacturing followed with incomes just under $140,000. Also exceeding the $80,000 average annual income level for all California manufacturing jobs in 2014 were Transportation Equipment Manufacturing, Machinery Manufacturing, and Medical Equipment & Supplies Manufacturing.

California Average Annual Earnings by Manufacturing Sector, 2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

INSIGHT

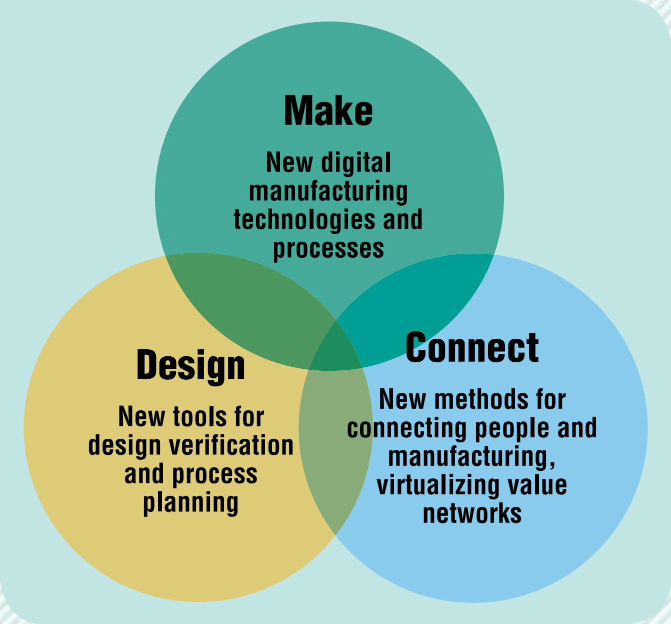
The Future of Making Things

Lawrence Lee, Tolga Kurtoglu, and Janos Veres, ***PARC, a Xerox company***

Breakthrough innovations seemingly burst into existence without warning. But on closer examination, we can see that they often occur when a new technology satisfies a fundamental human desire, such as creation, connection, or personalization, in an entirely new way. Blogs and Twitter enabled individuals to communicate with mass audiences. Instagram connected people across time and space through pictures. Amazon and eBay helped long-tail buyers and sellers find each other. We are seeing similar revolutions in healthcare, education, and transportation, enabled by mobile and social technologies that transform passive consumers into active participants.

Now digital technologies are making their impact in manufacturing, placing us at the dawn of a new era of consumer participation in how things are made. Early examples include the rise of production marketplaces and new crowdfunding models that not only provide seed funding but also allow designers to test demand ahead of investment. We have also seen the emergence of manufacturing services companies and incubators that simplify the complexities of offshore manufacturing.

Coming soon are dramatic advances in the democratization of technologies involved in creation and production. The next generation of design tools will allow consumers to create completely new products, not just customize them. The future of product development will be in the form of ad-hoc value networks that come together on a project-by-project basis, similar to how films are financed and produced in Hollywood. Driving these transformations will be advances in the underlying infrastructure of the digital manufacturing ecosystem, such as process modeling, expertise identification, risk analysis, "APIs" that connect contract manufacturers in virtualized supply chains, and radically simpler design tools that do not require expertise in 3D modeling.



PARC is investing in this vision of *The Future of Making Things* at the intersection of three areas: *Make, Design, and Connect*.

In the area of *Make*, it has been working to combine printed electronics capability with 3D printing to create functional objects with embedded sensors and computational components. Expanding additive manufacturing beyond shapes and colors is an exciting challenge, opening up on-demand fabrication of complex products. New types of raw materials, such as electronic materials and nanomaterials are needed, coupled with process technologies that allow us to manipulate them and deposit them accurately. One research direction involves printing with silicon chiplets, thus providing highly sophisticated building blocks for printing. Additive manufacturing—which is still seen today mainly as a prototyping technology—will engage us as creators of personalized products in terms of both form factor and functionality.

Ultimately these techniques will take additive manufacturing to a new level, enabling the integration of not only electronics, but also optics, actuation and fluidics towards "integrated objects." The impact of this is of similar magnitude to what it was with integrated circuits. Form and functionality will become seamless, enabling high levels of system integration in confined or distributed spaces, entirely new form factors, and freedom of design.

In area of Design, PARC has been modeling rapid prototyping and production capabilities of machine shops and developing a reasoning engine that can take a 3D model and automatically create a production "recipe" including process steps, allocation of consumables, and machine execution codes that normally would require an expert technician with years of experience. PARC is also creating analogous capabilities in reasoning for 3D printing and additive manufacturing processes.

In the area of Connect, PARC has been working to combine automated planning with distributed control in order to create reconfigurable production and distribution systems that can truly enable manufacturing to order, not to forecast. Going forward, it will be developing new process technologies using integrated design approaches that will start down the path to a flexible, ever-changing manufacturing ecosystem that can be connected and configured in new ways.

The Future of Making Things represents a breakthrough because it is not just about creating new technologies. At its core, The Future of Making Things is about empowering people to use their imagination to create things that serve their individual needs. We need to include social scientists on our innovation teams, to help us understand unexpressed human desires, and designers and usability experts to help optimize the user experience. We also need to include end users in our innovation process as we test and iterate in an agile manner.

We as a community of leaders in digital manufacturing research, technology, services, and policy will need to work together in a collaborative, learning-based process in order to realize all the components of this vision of The Future of Making Things. This will payoff with far-reaching benefits for our society, including new job creation in personalized commerce and local manufacturing, reduced greenhouse gases from supply chain related transportation, and new efficiencies and reduced waste from improved cradle-to-grave product and packaging design.

Regional Manufacturing Strengths

Manufacturing is distributed across the state, with distinctive regional clustering. Although manufacturing clusters are concentrated in urban centers, especially in Southern California, there are also pockets of producers in the state's rural areas. The eight regions defined in this analysis demonstrate distinct manufacturing strengths and trends, and each has evolved in a different way since 1990.

The *Los Angeles Area* is California's largest manufacturing hub. With 478,919 manufacturing jobs, the region accounted for 38.5 percent of the state's manufacturing employment and 8.4 percent of the Los Angeles Area's total employment in 2014.

The *Bay Area* is a leading global hub of technology innovation. Although it is one of the most expensive regions of the state, many manufacturers locate there because they work closely with the region's technology companies. The Bay Area's 293,847 manufacturing jobs made up 23.6 percent of manufacturing employment in California and 8.4 percent of Bay Area employment in 2014.

Orange County is the third largest manufacturing region in California, with 141,810 manufacturing jobs in 2014. It also has the highest concentration of manufacturing employment in the state, with manufacturing jobs accounting for 10 percent of the region's employment.

California's *Central Valley* is the heartland of the state's food production activity. Clustered around the cities of Bakersfield, Fresno, Modesto, and Stockton, its manufacturing sector accounted for 98,038 jobs in 2014 and 6.9 percent of total employment in the region.

Manufacturing accounted for 6.2 percent of total employment in the *San Diego Area* in 2014. Of the 84,615 manufacturing jobs in the region, a large portion are defense related.

Manufacturing accounted for 23,460 *Central Coast* jobs in 2014 and 4.1 percent of total employment in the region.

The 21,145 manufacturing jobs in the *Sacramento Area* accounted for only 2.4 percent of jobs in the region in 2014—the lowest regional share in the state.

In 2014, manufacturing accounted for 13,491 jobs in the *Northern California* region, or 4.0 percent of the region's employment.

For each of the eight regions, the California Manufacturing Regional Clusters analysis in Part Two provides 1990–2014 data on employment and establishments in 18 manufacturing sectors.

Manufacturing Employment and Establishments in California by Region, 2014

	Employment		Establishments	
		% Change 2010–2014		% Change 2010–2014
Los Angeles Area	478,919	0.7%	16,660	-5.7%
Bay Area	293,847	4.8%	8,257	-0.6%
Orange County	141,810	5.2%	4,857	-2.8%
Central Valley	97,037	10.9%	2,743	0.3%
San Diego Area	84,615	2.6%	3,096	1.6%
Central Coast	23,460	19.0%	1,538	7.7%
Sacramento Area	21,145	12.0%	1,386	-3.9%
Northern California	13,491	16.2%	976	-1.9%
CALIFORNIA TOTAL*	**1,243,329**	**3.1%**	**39,389**	**2.8%**

*Totals differ from the sum of the columns due to regional suppression.
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

INSIGHT

Next-Generation Technologies Drive Silicon Valley Manufacturing

David Wahl and Charlie Thayer, ***Jabil***

Silicon Valley, the heart of manufacturing? Yes. Jabil's new Blue Sky Center in San Jose facilitates a new era of manufacturing innovation with the Valley's brightest minds. Jabil provides manufacturing services for a wide range of industries in over 100 locations in 26 countries. It considered several global locations for its flagship Blue Sky Center before choosing San Jose. Many options were available including Jabil's headquarters in St. Petersburg, Florida. With its large Asia footprint, Jabil looked at locations like Singapore, Hong Kong, Shanghai and Taipei. Other innovation hubs in the US and Europe were also considered. In the end, Silicon Valley won out based on its concentration of the best universities and research institutes in the world and R&D investments by Fortune 100 companies, not to mention its ongoing leadership in start-up activities.

The Bay Area is world-famous for its heavyweight high-tech companies and venture capital funded start-ups. Many of its household name software companies are adding hardware and lifestyle products to their cache and are in need of a reliable local manufacturing partner. Entrepreneurial start-ups that exploit the latest technology trends need a manufacturer that can meet them on their level—nimbly developing advanced assembly processes and producing their futuristic products at start-up speeds. Jabil's San Jose hub seeks to revolutionize Silicon Valley's hardware manufacturing—everything from wearables and mobile health to autonomous cars and delivery drones.

Research and innovation engineering is critical to the manufacturing revolution. The Bay Area's renowned universities—Stanford, Berkeley, Santa Clara, and UCSF Medical as well as distinguished research institutes Lawrence Livermore, NASA Ames, SRI International and PARC—pioneer technology research that will enable novel products and new markets. This deep fundamental knowledge of materials science leads to next-generation technologies that Jabil utilizes, through local collaboration as well as recruiting, to accelerate innovation for manufacturing customers. Robotics, nanotechnology and materials science are capturing the interests of new top-tier graduates who previously would have been reluctant to pursue careers in manufacturing. Now Jabil is strategically placed to recruit from the world's brightest talent pool.

Advances in automation have moved manufacturing into a new era, reducing dependence on manual labor and ushering in a fresher, sleeker system that is thriving in California's high-tech areas. Jabil's Blue Sky Center is a strategically positioned repository of high-tech manufacturing solutions for Silicon Valley's innovative customers. Put your passport away, manufacturing is right here in San Jose.

INSIGHT

From Light Rail to Locomotives: Heavy Manufacturing by Siemens in Sacramento

Kirk Klug, ***Siemens Industry, Inc.***

Siemens Rolling Stock, part of the Siemens Mobility Division, is a global leader in the provision of railway and light rail rolling stock and services, manufacturing across the full spectrum of rolling stock including commuter and regional passenger trains, light rail and streetcars, metros, locomotives, passenger coaches and high-speed trainsets.

Contrary to the common belief that California no longer hosts heavy manufacturing, Siemens' Sacramento plant serves as the company's North American manufacturing headquarters, with capabilities spanning design, engineering, testing, carshells, bogies (wheelsets), subassembly and final assembly. Siemens has been manufacturing in Sacramento for more than 30 years. Committed to environmentally friendly processes, it uses solar energy to power more than 80% of its facility.

Since opening its doors, the plant's manufacturing portfolio has expanded from a core business building 1,300 light rail vehicles used in 17 cities in the U.S. and Canada, to include the production of streetcars and passenger rail locomotives and trainsets (650 foot long trains consisting of eight cars) for customers across North America. More than 850 people are employed at the 583,000 square foot facility, on 60 acres of land, which includes ready-to-build acres for a high speed rail center of excellence.

California's Innovation Ecosystem

California is not just home to a large and diverse manufacturing base; the state is also home to technology companies and research labs that are developing the tools for advancing any production process. The state's robust research base includes national labs, research universities and private research centers that are furthering advances in materials and technology and working with manufacturers to improve their products and process efficiencies. For example, labs and universities can support manufacturers by providing access to costly equipment and facilities; taking advantage of modeling and simulation capabilities at a lab or university can help a producer speed up prototyping and testing phases of new products.

The digitization of the economy includes the application of information and communications technology in the manufacturing arena—the so-called Industrial Internet. Collecting and analyzing data from production processes can improve efficiencies across multiple measures (e.g., materials, time, energy) and can improve quality control. In addition to process improvement, embedding technology such as communications, sensors, artificial intelligence, and analytics into products that were previously "unconnected" can enable entirely new products such as smart grid and smart agriculture (improving resource management and food safety). The generation of vast new sources of data is also creating new service models for producers like Tesla that collect data on their products after the point of sale in order to make ongoing improvements. Advances in data analytics have also enabled the rapid growth in quantitative biosciences.

The transformative Industrial Internet of Things (IIoT) wave has been led by industry majors like GE, IBM and Cisco, but early-stage companies are critically important, and the financial community is increasing its investment in industrial tech companies. Between 2010 and 2015, Internet of Things (IoT) start-ups overall attracted $7.4 billion in venture funding globally, according to CB Insights. With year-over-year growth in every year in that period except 2013, global yearly investment in Industrial Internet of Things start-ups rose from $182 million in 2011 to $1.045 billion in 2015, with an 83% increase from 2014 to 2015 alone. While covering a range of technologies, funding rounds in recent years have particularly focused on IIoT infrastructure, RFID-enabled supply chain sensors, and industrial robotics.[13]

The table on the following pages shows examples of companies providing the tools for advancing production processes.

Selected Companies Supporting Production Process Advancement

Company	Location	Industry	Description
Adept Technology	Pleasanton	Robotics & Software	Adept Technology, Inc. designs, manufactures, and markets robots for the electronics, telecommunications, appliances, pharmaceuticals, food processing, and automotive components industries. The company also designs the software to control manufacturing robots and set up automated assembly protocols.
Autodesk	San Rafael	Computer Aided Design (CAD) Software	Autodesk provides 17 products for the design of industrial equipment, including a complete factory design suite. Autodesk is best known for AutoCAD, but now develops a broad range of software for design, engineering, and entertainment, as well as a line of software for consumers. Autodesk's digital prototyping software is used in the manufacturing industry to visualize, simulate, and analyze real-world performance using a digital model during the design process.
CAD Design Services Inc.	Santa Clara	Industrial Design Services	CAD Design Services Inc. (CDS) provides standard and custom CAD and CAM software for physical layout, full 3D electrical and thermal model generation, and manufacturing of all types of semiconductor packages and printed circuit boards for any technology on any material, including lead frames.
Cisco	San Jose	Networking Equipment	Cisco Systems installs a "Connected Factory" architecture to streamline the movement of information between plants, branch IT networks, and headquarters by connecting all the IP ready devices, sensors, and robotics across a complete manufacturing operation.
E2open	Foster City	Supply Chain Management	E2open, Inc. is a provider of cloud-based, on-demand software that monitors a manufacturing supply chain. The application reports shortages and quality failures, along with potential alternatives, to a central dashboard for easy headquarters review.
FATHOM	Oakland	Additive Manufacturing Devices	The FATHOM portfolio includes professional 3D printing services, manufacturing systems, and prototyping which feature RTV/silicone molding and urethane casting, low volume CNC machining, injection molding, and more.
General Electric	Sunnyvale	Industrial Internet Data Systems & Analytics	General Electric is a transnational conglomerate corporation that provides a wide range of services in the home appliances, financial services, medical device, life sciences, pharmaceutical, automotive, software development and engineering industries.
Google	Mountain View	Cloud-based Design and Collaboration Tools	Google offers its cloud office suite (Google for Work) as a tool for manufacturers to collaborate on new designs and manage a supply chain in multiple countries. The Google App Engine also has manufacturing applications, allowing users to design process-specific software to help them adapt quickly to new product needs.
HP	Palo Alto	Supply Chain Management Software	HP offers software and data storage systems and software for supply chain monitoring and management. HP also offers data services to keep a manufacturer in compliance with the laws effecting each part of its supply chain.
IBM	San Jose	Industrial Internet Data Systems & Analytics	IBM provides analytics solutions for manufacturers in five main focus areas: sales and operations planning, predictive maintenance, demand planning and customer analytics, smarter supply chains, and streamlined sales compensation processes.
Keysight Technologies	Santa Rosa	Electronic Measurement	Keysight Technologies is a leading electronic measurement company, focusing on the transformation of the measurement experience through innovation in wireless, modular, and software solutions. Keysight provides electronic measurement instruments and systems and related software, as well as software design tools and services used in the design, development, manufacture, installation, deployment and operation of electronic equipment. (Keysight Technologies Inc. was separated from Agilent Technology in 2014.)

Company	Location	Industry	Description
Lawrence Livermore National Laboratory	Livermore	Scientific Research & Development	Lawrence Livermore National Laboratory (LLNL) was established by the University of California as a research and development institution. Lawrence Livermore National Security, LLC assumed management of the Laboratory in 2007. LLNL focuses on research and development advances in the biosecurity, counterterrorism, defense, energy, intelligence, nonproliferation, and weapons industries.
Nanometrics, Inc.	Milpitas	Industrial Machinery & Equipment	Nanometrics provides advanced, high-performance process control metrology and inspection systems used primarily in the fabrication of semiconductors and other solid-state devices. Nanometrics' automated and integrated metrology systems measure critical dimensions, device structures, overlay registration, topography and various thin film properties. Nanometrics' systems enable advanced process control for device manufacturers and are deployed throughout the fabrication process, from front-end-of-line substrate manufacturing, to high-volume production of semiconductors and other devices, to advanced wafer-scale packaging applications, providing improved device yield at reduced manufacturing cycle time.
Power Standards Lab	Alameda	Industrial Equipment	Power Standards Lab (PSL) specializes in power quality testing and certification and is a global hub of engineering information about electric power measurement and immunity to electric power disturbances. Providing power quality testing both on site and in its lab, PSL certifies power quality instruments to make sure they use the same definitions and measurement techniques for various power quality parameters: sags/dips, swells, frequency, harmonics, flicker, etc. PSL tests semiconductor fabrication equipment for voltage sag immunity and offers recommendations on how to improve immunity as well.
Production Robotics	San Leandro	Robotics	Production Robotics provides contract automation engineering, machining and manufacturing services to companies in the biotechnology, diagnostics, microsurgery, pharmaceutical packaging, food processing, electronics manufacturing and automotive industries. In addition to engineering and development services, Production Robotics also provides contract fabrication, assembly, testing, packaging and shipping of electromechanical products and subassemblies.
Siemens	Mountain View	Industrial Internet Data Systems & Analytics	A leading supplier of systems for power generation and transmission as well as medical diagnosis, Siemens focuses on the areas of electrification, automation and digitalization. One of the world's largest producers of energy-efficient resource-saving technologies, Siemens provides products and systems for industrial communication to ensure company-wide efficiency using integrated, high-performance data networks that can be implemented to meet extreme environmental requirements.
Trio-Tech International	Van Nuys	Testing Services and Equipment	Trio-Tech International offers test equipment and testing services to the microelectronics industry, particularly semiconductor testing and burn-in services. Besides the semiconductor industry, Tri-Tech also provides services to the avionics industry, defense sectors, medical industry, and research institutes, as well as OEM/ODM manufacturers. Tests performed include stabilization bake, thermal shock, temperature cycling, mechanical shock, constant acceleration, gross and fine leak tests, electrical testing, microprocessor equipment contract cleaning services, static and dynamic burn-in tests, reliability lab services and vibration testing.

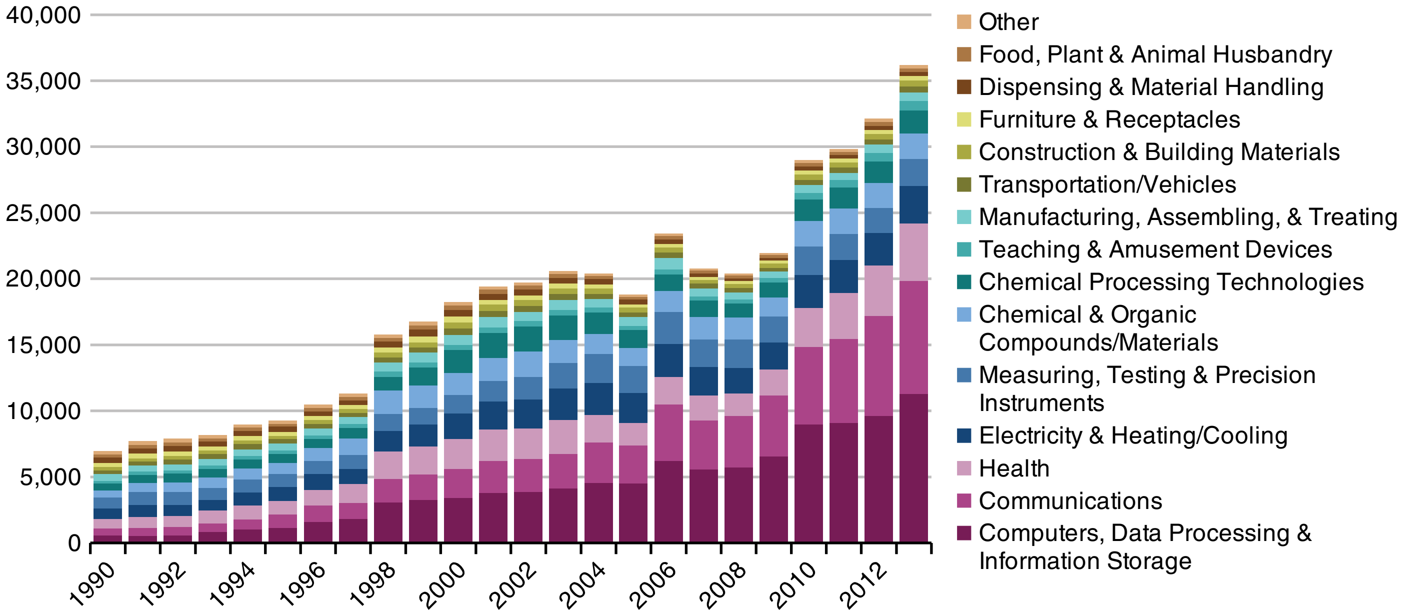
Patent Activity

Patents registered to California inventors represented approximately 10 percent of total US patent registrations in 2013. A total of 36,193 patents were registered to primary inventors located in California; this number has increased by a factor of four since 1990. Thirty-one percent of those patents are registered in the Computers, Data Processing, and Information Storage field, which has produced an average annual growth rate of 15.2 percent. This category includes computer hardware as well as code and methodology for data processing and storage. Other sectors have also grown quickly, including Communications and Health, which have experienced annual growth rates of 13.5 percent and 9.4 percent, respectively. The number of Transportation/Vehicles patents, another high growth area in manufacturing, has also been rising. Together, these four categories made up nearly three-quarters of the state's patent activity in 2013.

California's patent registration growth relates closely to the state's strong manufacturing activity. California ranks second (following Michigan) in the number of patent registrations in the category of Manufacturing, Assembling, & Treating. While overall patent registrations within California in this category declined by more than 40 percent between 2006 and 2009 (in line with a broader downturn in patent activity), patent registrations began to ramp back up starting in 2010.

California's patent activity is highly concentrated in the Bay Area. With 153,436 registered patents, or 61.3 percent of all California patent activity, the Bay Area has registered more patents between 2004 and 2013 than all other regions combined. This large share of patents in the Bay Area is due to the region's specialization in the largest seven patent categories in the state. No other single region has registered more than half of the patents in any category, but other regions do show pockets of concentration.

Annual California Patent Registrations by Category, 1990–2013

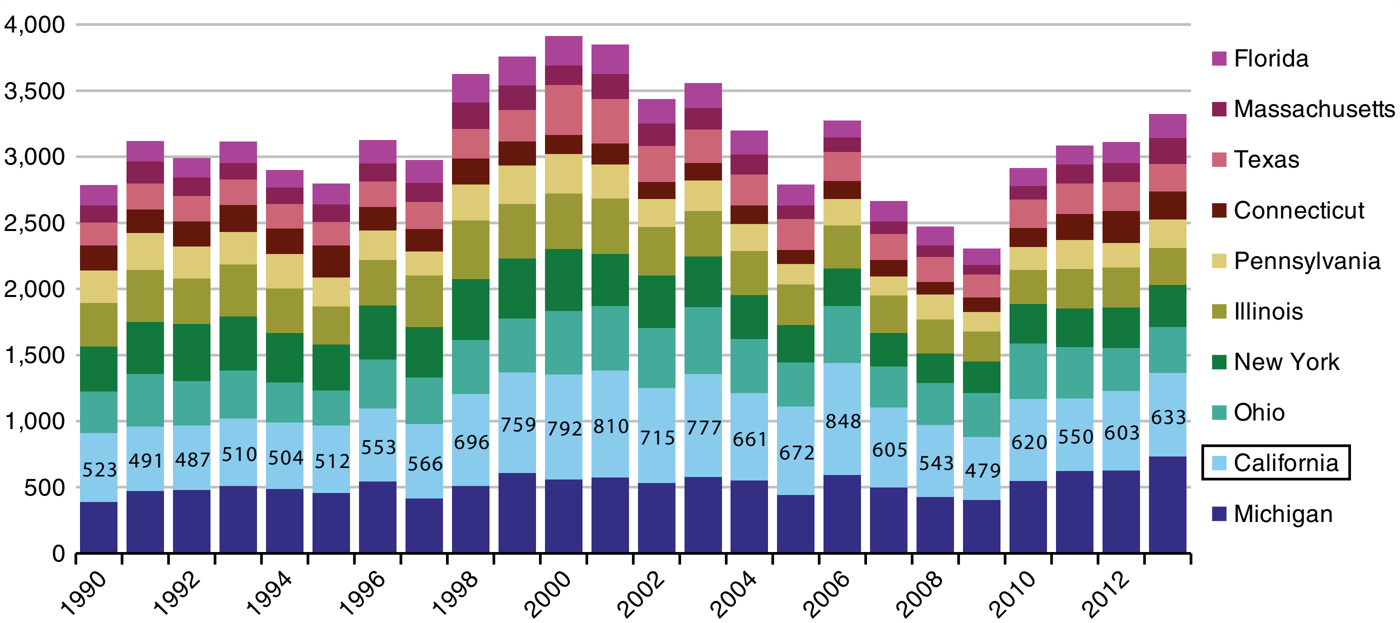


Note: Patents are reported if the first named inventor was located in California. "Other" includes Apparel, Textiles & Body Adornment, Ammunition & Weapons, Nuclear Technology, and Superconducting Technology
Data Source: US Patent and Trademark Office
Analysis: Bay Area Council Economic Institute

While Southern California regions have a large number of patents in high-tech categories, they show relative strength in categories such as Furniture & Receptacles, Apparel & Textiles, Teaching & Amusement Devices, and Construction & Building Materials. The Los Angeles Area shows particular strength in furniture and apparel patents, with statewide shares of 41 percent and 38 percent, respectively. The San Diego Area has concentrations in Communications and Chemical & Organic Compounds, while Orange County has a high percentages of activity in Building Materials and Transportation/Vehicles.

Central California and the Sacramento Area combine to account for over one-quarter of all California patent activity in Food, Plant, & Animal Husbandry. Central California also shows a concentration in Ammunition & Weapons, even though the region itself makes up less than 5 percent of California patent activity. Northern California and the Sacramento Area are notable for their activity in Dispensing & Material Handling.

Manufacturing, Assembling, & Treating Patent Registrations, 1990–2013: Top Ten States



Note: Patents are reported if the first named inventor was located in each State.
Data Source: US Patent and Trademark Office
Analysis: Bay Area Council Economic Institute

Regional Shares of California Patents by Technology Area, 2004–2013

	Total Patents	Bay Area	Los Angeles Area	San Diego Area	Orange County	Central California	Sacramento Area	Northern California
Computers, Data Processing & Information Storage	71,622	76.0%	6.5%	5.8%	4.6%	4.3%	2.6%	0.2%
Communications	50,261	60.4%	10.0%	16.6%	8.0%	3.3%	1.5%	0.3%
Health	25,769	51.2%	18.2%	14.7%	11.2%	3.3%	1.2%	0.2%
Electricity & Heating/Cooling	23,412	63.2%	14.1%	6.7%	8.4%	5.0%	2.2%	0.4%
Chemical Processing Technologies	14,280	71.7%	11.1%	5.3%	5.2%	5.5%	1.1%	0.2%
Measuring, Testing & Precision Instruments	20,755	59.6%	18.8%	8.0%	6.0%	5.9%	1.3%	0.3%
Chemical & Organic Compounds/Materials	16,796	58.7%	12.8%	18.3%	5.1%	3.1%	1.9%	0.1%
Manufacturing, Assembling, & Treating	6,114	43.3%	24.0%	8.7%	11.5%	8.7%	2.4%	1.4%
Teaching & Amusement Devices	4,310	24.4%	31.1%	28.1%	9.3%	4.4%	1.8%	1.0%
Construction & Building Materials	3,657	34.2%	24.6%	6.4%	22.8%	7.4%	3.4%	1.3%
Transportation/Vehicles	3,649	20.2%	37.2%	12.3%	17.1%	8.9%	2.9%	1.3%
Dispensing & Material Handling	2,859	29.2%	31.9%	11.1%	14.3%	8.0%	3.4%	2.1%
Furniture & Receptacles	2,773	23.2%	41.2%	10.7%	14.8%	6.9%	2.1%	1.3%
Food, Plant & Animal Husbandry	2,262	26.5%	23.0%	10.7%	10.9%	16.7%	10.3%	1.9%
Apparel, Textiles & Body Adornment	1,230	21.3%	38.4%	11.5%	17.2%	7.9%	3.0%	0.7%
Ammunition & Weapons	441	17.2%	33.6%	5.7%	14.1%	25.4%	1.1%	2.9%
Nuclear Technology	92	79.3%	3.3%	6.5%	5.4%	5.4%	0.0%	0.0%
Superconducting Technology	25	40.0%	44.0%	0.0%	0.0%	16.0%	0.0%	0.0%
Total percentage of patent registrations	250,307	61.3%	13.4%	10.7%	7.6%	4.6%	2.0%	0.4%

Note: Highlighted cells denote the three most concentrated technology categories in each region. Patent counts refer to all utility patents whose first-named inventor is located in each region.

Data Source: US Patent and Trademark Office

Analysis: Bay Area Council Economic Institute

INSIGHT

Decoding the DNA for an Effective NDA

Joshua Cohen, *Wendel, Rosen, Black & Dean, LLP*

Collaboration across industries in manufacturing sectors creates opportunities for spurring innovation within companies, industries and regional economies, but collaboration can also pose substantial risks. Enthusiastic about new business opportunities, manufacturers often begin sharing their proprietary information before taking the necessary precautions. Just as one would not share one's social security number on a first date, manufacturers need to be cautious about what they share with potential business partners.

Most companies are familiar with non-disclosure agreements (NDAs), but unfortunately many companies simply pull an NDA off the Internet—which is akin to buying a wedding dress on Craig's List: it isn't going to fit. Still worse, companies often begin disclosing proprietary information before the NDA is fully executed.

Who Needs an NDA? Whether producing potato chips or microchips, manufacturers often have trade secrets that give them a competitive advantage. Customer lists, vendor lists, pricing, salaries, five-year business plans and the techniques developed to manufacture products faster, cheaper and better than competitors are all proprietary information that companies want to remain secret.

Under the Uniform Trade Secrets Act, there are two prongs to a trade secret:

> (1) the information must provide the owner with independent economic value by not being generally known to the public or those in the relevant industry; and
>
> (2) the owner must have taken reasonable efforts to keep the information secret.

Sharing propriety information with a potential business partner, a manufacturer exposes a company to two risks. The obvious first risk is that the potential partner uses that information to compete or leaks that information to a competitor. The less obvious risk is that the partner fails to make reasonable efforts to keep the information secret. When a company shares its secrets with a potential partner without an NDA and a competitor obtains the secrets, even from an independent source, the courts are unlikely to enforce the company's rights in a lawsuit against the competitor because the company's failure to obtain an NDA from a potential partner will be used as evidence that the company failed to make "reasonable efforts" to secure its secret.

What Is in an NDA? Manufacturers need to be consistent. To protect its secrets, a company needs to obtain NDAs from everyone with access to the company's information, including employees, existing business partners and potential business partners. The company needs to be explicit. An NDA that provides that "Company B acknowledges that Company A's widget testing process has economic value and is not generally known" is much stronger than a boilerplate NDA that merely provides that "Company B acknowledges that Company A has proprietary information that constitutes trade secrets." If a potential partner is in the same industry, a manufacturer may want to include an anti-solicitation provision, which prevents the partner from actively poaching the company's employees. The NDA should also require the potential business partner to return all proprietary information to the company at the end of the partnership.

Finally, an NDA needs to have teeth. The NDA should include language saying that a potential breach could result in irreparable harm and that the company is entitled to seek injunctive relief, i.e., it has the right to seek immediate court intervention rather than wait months or years for a trial. The NDA should also identify the venue and jurisdiction (e.g., "the Los Angeles Superior Court") where any dispute shall be resolved so valuable time is not wasted arguing over the proper forum.

Whether manufacturers are meeting with potential investors, technology companies or vendors, they can benefit from developing an appropriate NDA and ensuring that it is fully executed before sharing any proprietary information.

3

Strengthening California's Environment for Manufacturing

Long-standing notions about manufacturing in the US are being upended as a result of technological advance and changing cost factors globally. New technologies, such as 3D printing and other digital tools,[14] are playing growing roles in manufacturing and are pushing down labor's share of total production costs. As cost factors shift, manufacturers are beginning to move operations closer to end markets,[15] while others are moving back to the US due to intellectual property, quality, and time-to-market issues that are better controlled domestically.

Given stagnating household incomes nationally and producers' concerns about skills shortages, manufacturing has become the focus of resurgent interest both because it is a source of middle-income jobs with career paths and because it has the potential to drive a new wave of innovation. Manufacturing is key to the strength of the US economy for multiple reasons, including its 12.1 percent share of gross domestic product in 2015,[16] and its workforce of over 12.3 million.[17] In addition to its role in direct job creation, manufacturing has the following economic impacts:

Manufacturing generates high levels of output and employment throughout the economy. Studies have found that each manufacturing job creates more than two additional jobs, compared to multipliers of 1.5 for jobs in business services and below 1.0 for retail trade.[18] Every dollar in final sales of manufactured products supports $1.37 in additional economic activity—more than double the multiplier effects for the retail and wholesale trade sectors.[19]

Manufacturers are responsible for approximately 70 percent of all research and development (R&D) conducted by private businesses in the US. R&D spending in manufacturing grew from 8 percent of sales in 2000 to 11 percent in 2008, and has remained relatively flat since.[20] Over the period from 2000 to 2008, 22 percent of manufacturing companies reported product or process innovations compared to only 8 percent of non-manufacturing companies.[21] This concentration of R&D spending in manufacturing is the backbone of the domestic innovation infrastructure, much of it occurring in high-technology sectors such as pharmaceuticals (23 percent of total private US R&D spending), aerospace (19 percent), and electronic instruments (12 percent).[22]

Manufacturing is the largest contributor to US exports, with nearly $1.2 trillion exported in 2014. Manufactured goods account for 74 percent of all US goods exports and 51 percent of total exports.[23]

While California may not have a competitive advantage for all types of manufacturing, there are sectors that are well positioned to thrive in the state. Particular examples include the manufacturing of products that are time-sensitive and products such as foods and beverages that are location specific, as well as R&D-intensive products of an advanced technological nature.

Manufacturing in California, ranging from food and beverages to technology products, is deeply integrated into the state's innovation ecosystem. Often, early-stage manufacturing will be located close to a company's R&D facility to allow industrial process managers to interact with researchers as new products are developed and modified. In other cases, producers stay competitive on the global market through their close partnerships with local technology companies and research centers.

As production factors shift, some manufacturers will look to locate closer to their end markets or to improve their proximity to innovation hubs, supply chain networks, and labor pools. The cost of doing business—including regulatory compliance, land and infrastructure availability, and access to capital and financial incentives—will play a greater role in manufacturing location decisions as well, especially as firms look for critical cost advantages.

In California and across the nation, advances in automation that enable increased productivity with fewer workers than in the past will impact the skill sets needed. Manufacturing jobs will remain an essential source of middle-wage jobs, vital for a thriving, competitive economy. Specific actions can be taken to support the growth and advancement of manufacturers in California and to develop the workforce its producers need.

Stimulate the Commercialization of Research and Development through Cluster-Based Strategies

Manufacturing has undergone multiple shifts over the last 20 years, beginning with the movement of low-value manufacturing processes to lower-cost locations. In addition to the loss of many American manufacturing jobs, offshoring portions of the US manufacturing base risks the related offshoring of innovation. Historically, the offshoring movement first shifted lower-end production and later higher-value activities, including applied research and development. Over time, more R&D followed manufacturing to overseas locations, calling into question the model where manufacturing is allowed to leave but advanced R&D is presumed to remain a domestic strength.

Critical components of the manufacturing ecosystem—including knowledge and skills, supply chain vendors, tools, and production equipment—have been lost in industries that have undergone extensive offshoring. Because of this movement overseas, many high-tech products can no longer be manufactured in the US,[24] such as compact fluorescent lighting; LCD displays for monitors, televisions, and mobile devices; lithium-ion batteries for cell phones; consumer networking hardware such as routers and set-top boxes; and advanced composites and ceramics. The US has also lost the ability to manufacture key categories of high value steel.

To address these losses, national manufacturing policies are increasingly embracing regional cluster strategies. These networks often include public research institutions, such as universities and national laboratories. The goals of recent national manufacturing policies have been centered on rebuilding an industrial commons—a term used to define the knowledge assets and physical facilities that are shared between production firms; suppliers of materials, components, and production equipment; and research and development facilities, which are often geographically concentrated.

A recent federal initiative highlights this industrial commons approach. In 2014, Congress appropriated $300 million over 10 years to the National Network for Manufacturing Innovation (NNMI) Program to build a network of 15 institutes that would seek to bring together regional manufacturing stakeholders from industry, government, and academia with the goal of facilitating advanced manufacturing processes from basic research to implementation. With investments coming from the Department of Defense and the Department of Energy, seven NNMI Program institutes were established by the end of September 2015.

> *America Makes: The National Additive Manufacturing Innovation Institute*, Youngstown, Ohio: Launched in August 2012 with $30 million in federal funding and opened in October 2012, this institute is devoted to helping the US grow its capabilities in 3D printing by fostering collaboration in design, materials, technology, and workforce.
>
> *PowerAmerica: The Next Generation Power Electronics Manufacturing Innovation Institute*, Raleigh, North Carolina: Opened in January 2015, this institute is focused on enabling the manufacturing of energy-efficient, high-power electronic chips and devices, by making new semiconductor technologies cost-competitive with current silicon-based power electronics.
>
> *Digital Manufacturing and Design Innovation Institute*, Chicago, Illinois: Opened in May 2015, this institute is focused on enabling interoperability across supply chains and on developing enhanced digital capabilities to design and test new products.
>
> *LIFT: Lightweight Innovations for Tomorrow*, Detroit, Michigan: Opened in January 2015, this institute works to speed the development of new lightweight metal and manufacturing processes for products with warfighting, aerospace, automotive, and other applications.
>
> *Institute for Advanced Composites Manufacturing Innovation*, Knoxville, Tennessee: Opened in June 2015, this institute is focused on lowering the costs and reducing the energy needed for the manufacturing of advanced composites, in order to enable their use in a broader range of products including lightweight highly fuel-efficient vehicles and lighter, more efficient industrial equipment.
>
> *AIM Photonics: American Institute for Manufacturing Integrated Photonics*, Rochester, New York: Announced in July 2015, this institute will advance technology development for the manufacturing of integrated photonics circuits, which allow the placement of thousands of photonic components (such as lasers, detectors, waveguides, modulators, electronic controls, and optical interconnects) on a single chip, enabling faster data transfer capabilities.
>
> *NextFlex: Flexible Hybrid Electronics Manufacturing Innovation Institute*, San Jose, California: Announced in August 2015, this institute's activities will benefit a wide array of markets including defense, automotive, communications, consumer electronics, medical devices, healthcare, transportation, and agriculture.

The federal government has also launched two additional manufacturing innovation institute competitions—one focused on revolutionary fibers and textiles, and one focused on smart manufacturing, advanced sensors, and process controls.

California Initiatives to Link R&D and Manufacturing

California has secured one NNMI site in San Jose, and the state is also a national leader in federally-sponsored R&D awards, which often take the form of research performed through academic institutions and companies. In fiscal year 2013, the federal government placed $16.3 billion in research obligations within California, ranking it first among states with approximately 13.1 percent of the total for R&D awards in all states.[25] Only one other state—Maryland with $15.9 billion in awards—surpassed the $10 billion level.

Taking advantage of its strength in public research, California launched the Innovation Hub (iHub) program in 2010 in an effort to harness and enhance the state's innovative networks. The iHubs seek to improve the state's competitiveness by stimulating partnerships and job creation around specific research clusters. The iHubs leverage assets such as research parks, technology incubators, universities, and federal laboratories to provide an innovation platform for start-up companies, economic development organizations, and business groups.

Today, 16 iHubs span the state, each with a distinctive model for coordinating research and business activities. Examples of iHubs and their strategies include the following:

> *Collaborating with National Laboratories*: The i-GATE iHub in Livermore receives partnership support from Lawrence Livermore National Laboratory and Sandia National Laboratories.
>
> *Leveraging Academia*: The Clean Tech LA iHub in Los Angeles supports technology commercialization through collaborations with UCLA, USC, and Caltech.
>
> *Connecting Start-Ups to Opportunities*: Multiple iHubs, including those located in San Diego, San Francisco's Mission Bay, Chico, and Santa Rosa, support entrepreneurs by providing physical infrastructure and business services.

SPOTLIGHT

CalCharge: Charging Battery Manufacturing in California

In an effort that mirrors the iHub program, more than 80 battery technology companies have formed a California public-private partnership around energy storage. CalCharge began as a joint effort of Lawrence Berkeley National Laboratory, San Jose State University, SLAC National Laboratory, and the International Brotherhood of Electrical Workers. Its membership now includes a consortium of companies such as Duracell, Hitachi, Volkswagen, LG, and Eaton Corporation, as well as Bay Area start-ups, including EnerVault, Primus Power, and Halotechnics.

The organization's mission is to support battery companies as they evolve from idea to prototype to product. CalCharge provides this support through its partner laboratories, which have streamlined their processes for allowing outside firms to conduct research. Providing laboratory space and access to scientific equipment reduces the barriers to entry into the battery sector, and companies can develop their ideas sooner and with lower initial costs. CalCharge will also assist start-ups with locating Bay Area manufacturing space, as maintaining close proximity between engineering innovations and manufacturing will be critical in the highly technical energy storage sector.

SPOTLIGHT

Building a Biomedical Manufacturing Network

Based in the East Bay and funded by the US Department of Energy's Office of Energy Efficiency & Renewable Energy (EERE), Bio-Manufacturing to Market is a UC Berkeley initiative which is part of the Advanced Manufacturing Jobs and Innovation Accelerator Challenge grant. It is a member of the Biomedical Manufacturing Network, which was co-founded by UC Berkeley and works to support biomedical entrepreneurship, manufacturing, and commercialization in the Bay Area.

The Biomedical Manufacturing Network was formed in 2013 after a partnership of regional entities won a US Advanced Manufacturing Jobs and Innovation Accelerator Challenge grant funded by the US Departments of Commerce, Energy and Labor, the US Small Business Administration, and the National Institute of Standards and Technology (NIST). Today it engages more than 700 biomedical manufacturing companies in the Bay Area—the largest biomanufacturing cluster in the world—providing business services and placing interns with companies. It maintains a database of over 1,000 university and federal laboratory technologies that are available for transfer to companies, and it publishes reports on talent, manufacturing technology, and commercialization in the biomedical industry. In a partnership that operates under the Biomedical Manufacturing Network's umbrella, Oakland's Laney College and UC Berkeley jointly support a Bioengineering Certificate Program that offers training at both UC Berkeley and Laney College for both students and current workforce participants who need retraining.

Recommendations to Bolster California's Clusters of Innovation Related to Manufacturing

Leverage capabilities across California iHubs, and within individual iHubs, through a dedicated statewide funding mechanism.

Currently, the iHub system operates without any state funding. Instead, iHub activities have been funded through external partnerships—that often then dictate the iHub's strategies going forward. If the Governor's Office of Business and Economic Development (GO-Biz) were to provide a pool of competitive funds based on targeted metrics and goals, iHubs could be more effective and accountable in expanding the innovation infrastructure that underlies advanced manufacturing. Competitive funding also creates an opportunity for iHubs with overlapping capabilities or geographies to partner together to further their reach.

Invest in shared manufacturing spaces and provide avenues for small manufacturers and start-ups to engage with and commercialize new technologies and processes.

Particularly in portions of the state where national laboratories do not exist, there are opportunities for the state to invest in high-tech facilities with state-of-the-art equipment that can support specific innovative regional clusters. An example of this approach is New York State's commitment of $225 million to investments in the Buffalo/Niagara region that would build a cluster of green energy businesses.[26] The money will go toward state-owned facilities that will house equipment and machinery that clean energy firms need to develop new products but cannot easily afford on their own. To catalyze participation among a wide range of manufacturers in similar programs, California can employ a strategy resembling the small business voucher program used in some national labs. Small manufacturers would submit business plans to a governing body that would select companies to participate in the shared facility. These manufacturers would then be given credits to be spent through utilization of equipment and other business assistance.

Create improved coordination across engineering research functions at University of California campuses.

Similar to the multi-state strategy employed by the NNMI designee headquartered in Tennessee—which includes participants from eight states—future California applications for federal grants could consider ways to better leverage competencies and areas of specialization across the UC system. For example, UC Davis has a well-regarded machine tools program; UC Irvine's core competencies include defense-related applications and medical devices; UCLA has a smart manufacturing research center; UC Berkeley is a leader in sustainable manufacturing; and UC Santa Barbara has core strengths in materials. Creating cross-campus partnerships in an application supported by businesses and other research and manufacturing organizations across the state would allow California to better leverage the assets concentrated in distinctive regions.

Grow the Talent Base for Advanced Manufacturing

The manufacturing sector faces a growing talent gap that could stall its growth. As technological improvements have changed the landscape of industry in the US, manufacturing jobs have shifted from low-skill assembly line positions to more advanced production roles, such as machinists, tool and die makers, robotics operators, and technicians. Also growing in concentration in manufacturing are PhD scientists in such fields as advanced materials, chemistry, biotechnology, and physics. While these jobs have all evolved, the educational systems that train workers in the skills for advanced manufacturing have shifted at a slower pace.

In a 2011 Deloitte survey of manufacturers, 74 percent of respondents indicated that workforce shortages or skill deficiencies in production roles were having an impact on their ability to expand operations or improve productivity. In some cases, the loss of manufacturing activities has eroded the technical skills base, pushing manufacturers to locate in other locales.

The skills gap in manufacturing is also generational. As companies shifted production abroad, manufacturing trades became less attractive to students. To highlight this gap, the American Welding Society estimates that the average age of the American welder is 55.[27] As these workers approach retirement, a new generation of workers will be needed to replace them on the production floor. However, many younger workers lack the skills necessary to be successful in the advanced manufacturing economy. Given a weak pipeline of manufacturing talent, manufacturers have cited a need to interview more candidates in order to find qualified individuals, and a lack of basic familiarity with precision manufacturing tools among new hires has increased turnover.[28] This problem will worsen as large numbers of highly experienced workers near retirement.

California Initiatives to Match Training with the Needs of Employers in Manufacturing

Of the $4.3 billion spent annually by the federal government on technology-oriented education and training, only one-fifth goes toward programs supporting vocational and community college training programs.[29] Given this level of national funding, California workforce programs for manufacturing have been centered on better utilization of the community college system to place students on career paths in manufacturing.

Under the *California Community Colleges Economic and Workforce Development Program*, industry-specific workforce services are coordinated by regional Deputy Sector Navigators who align community college and other workforce development resources with the needs of industry sectors. Advanced manufacturing is one of 10 priority areas under the program, with goals that include identifying and filling gaps in community college curricula with the help of industry partners and attracting more students to career paths in manufacturing and other technical areas.

The *Career Technical Education Pathways Initiative* aims to engage learning institutions at all levels in improving linkages, increasing readiness of secondary students for postsecondary education, and increasing student success and training in postsecondary education. Grants provided through the program help in the development of local and regional career technical education pathway systems. For example, the *Bay Area Community College Consortium* is developing new curricula with eight colleges and 28 manufacturing industry partners to strengthen the alignment of training programs with regional industry needs. It has also created work-based learning opportunities at six Bay Area companies.[30]

SPOTLIGHT

San Diego Workforce Development Activity

The San Diego region is home to two innovative workforce development programs for advanced manufacturing.

The *Workshops for Warriors Program* is dedicated to training, certifying, and placing veterans into advanced manufacturing careers. Founded as a way to assist veterans' transition to civilian life, Workshops for Warriors is a nonprofit organization that operates a half-acre industrial campus where its students are able to learn machining and welding techniques on equipment donated by or leased from area manufacturers. The program is up to 16 months in duration and results in credentials from the industry's leading bodies (the American Welding Society, the National Institute for Metalworking Skills, Mastercam University, and Solidworks). To date, 170 veterans have completed the program at no cost to them, and the program boasts a job placement rate of 100 percent. The waitlist for Workshops for Warriors now tops 400 veterans.

Quality Controlled Manufacturing Inc. (QCMI), a precision machining manufacturer based in Santee, California, partnered with the San Diego Workforce Partnership to establish the QCMI Machinist Training Program in 2014. Through a structured curriculum created by expert machinists at QCMI, students are taught shop theory, blueprint reading, safety principles, machining, and quality control. Students also complete a final project in which they create sketches and a machining program and utilize fabrication tools to produce an actual part. The program had its first graduates from the six-month course in April 2015. Graduates also receive assistance in finding positions within QCMI or other area manufacturers. Future students will be brought into the program through factory tours and veterans associations.

Recommendations to Enhance California's Manufacturing Workforce

Initiate apprenticeship programs to build skills for new workers and to train those that are changing fields.

Corporate apprenticeship programs can be used to draw younger workers into the manufacturing field in California. By combining classroom training with on-the-job experience, the costs of training new employees for manufacturing skills can be split between the educational system and industry. Germany employs the best practice apprenticeship model under which two-thirds of the country's manufacturing workers are trained through partnerships among companies, vocational schools, and trade guilds.[31] Germany's system is part of the reason the country's youth unemployment rate is below 8 percent, less than half of the rate in the US.[32] Switzerland offers another successful example of public-private cooperation to support manufacturing and other skills development through apprenticeships.

Domestically, the Department of Labor supports public-private partnerships that establish apprenticeship programs in advanced manufacturing. At the state level, South Carolina has been able to stimulate apprenticeships through a $1,000 tax credit per year per apprentice.[33] A similar initiative in California can be tailored to small and medium manufacturing enterprises that cannot otherwise afford the in-house training programs that will be needed to bridge skill and generational gaps going forward.

Support state-funded technical education programs through sustained funding connected to metrics for effectiveness.

The 2015–2016 California state budget established the Career Technical Education Incentive Grant Program to spur partnerships between school districts, colleges, and businesses. The budget provides $400 million, $300 million, and $200 million in each of the next three years, respectively, for competitive grants. These grants would require a dollar-for-dollar match and proof of effectiveness across a range of outcomes such as graduation rates, course completion rates, and the number of students receiving industry credentials.[34] Additionally, the 2015–2016 California state budget extended the Career Technical Pathways Initiative by one year, which will sustain a program that has been in existence since 2005 and can be instrumental in promoting advanced manufacturing career exploration for community college students. Attention should also be paid to the sustainability of these programs after state funding expires.

Adopt a statewide certification for advanced manufacturing skills across strategically selected schools.

California can develop a manufacturing certification model that allows students to sequence credentials over time to build comprehensive advanced manufacturing skills. These certifications should range from machining and tool and die making to maintenance technician and quality control skills. They should also be compatible with the National Association of Manufacturers' skills certification system, so that the credential can be transferred to work in other states. Designating strategic community colleges as "manufacturing schools" could also sharpen the manufacturing focus across the state and give regional industry participants a more streamlined means to participate in curriculum development and to recruit future workers.

Pursue higher goals for incorporating STEM education and its associated career pathways into curricula for elementary and high schools.

Educational objectives in Science, Technology, Engineering, and Math (STEM) continue to be high priorities in school districts around the state. Programs that bring robotics, machining, and other applied technologies into K–12 classrooms can begin to fill the talent pipelines needed for advanced manufacturing in the state. By reaching students at an earlier age, these types of programs can provide awareness of the options available to students who may not wish to pursue a four-year degree, and these programs can increase the knowledge and appeal of manufacturing careers.

Provide Access to Capital and Financial Incentives for Manufacturers

Clustering and workforce initiatives can provide the long-term structural changes necessary to move advanced manufacturing in California forward. More immediately, the availability of capital plays a key role in a firm's ability to grow, and financial incentives often can determine siting locations as manufacturers expand.

At the national level, the federal Research and Experimentation Tax Credit provides $7 billion in tax incentives each year to companies that make investments in research.[35] This tax credit allows firms to generate a higher rate of return on their research programs and also boosts the total dollars invested in research and development. A New York University study estimated that a 10 percent reduction in the cost of R&D leads the average firm to increase its research intensity—the ratio of R&D spending to sales—by 11 percent.[36]

While manufacturers have called for lower effective corporate tax rates at the federal level,[37] California tax policies have also played a role in manufacturers' decisions on where to locate and invest. With an 8.84 percent state corporate tax rate, California has the 10th highest rate in the country.[38] Other states, such as Nevada, Washington, and Texas, do not tax corporate earnings. Aside from taxing earnings, many states tax real property, tangible personal property, and corporate net worth (i.e., franchise taxes); business purchases of equipment are also taxed in many jurisdictions via the state sales tax. Taken together, these tax burdens can be a determining factor in where a company decides to make new investments.

One area for possible reform that could lower the absolute tax amount paid by manufacturers in California is the state's tax on tangible personal property. Income-generating movable assets, such as machinery used in manufacturing, fall under the definition of tangible personal property. In California, this property is taxed at a rate of 1.22 percent; however, 12 states exempt new machinery and equipment from this tax to varying degrees. California's 7.5 percent sales tax rate is also the highest in the nation, though the state has already taken steps to partially exempt manufacturing equipment from this tax.

California Programs to Incentivize Manufacturing Within the State

To assist manufacturers expanding their operations within the state or looking to relocate, the State of California has created a package of incentives.

The *California Competes Tax Credit* is negotiated between GO-Biz and businesses wanting to come to California or grow within the state. Credit amounts depend on the number of jobs that will be created in California and the amount of investment by the business. Of the $151.1 million of tax credit available in fiscal year 2014–2015, 25 percent was reserved for small businesses with sales less than $2 million.

For each taxable year between 2014 and 2020, the *New Employment Credit* is available to a tax-paying business that hires a full-time employee. The work performed by the employee must occur within an economic development area designated by the state, based on employment and poverty levels. In order to qualify for the credit, the business must have a net increase in the total number of full-time employees in California.

Eligible manufacturers can finance capital projects through *Tax-Exempt Industrial Development Bonds*, which are issued by a local authority—such as an economic development authority or joint powers authority—and are approved by the California Industrial Development Financing Advisory Commission. With a lower cost to borrow stemming from the tax-exempt status, manufacturers can use the bond proceeds to finance the acquisition and rehabilitation, or construction of manufacturing facilities.

Like many other states, California provides a *partial sales tax exemption for manufacturing equipment*. The exemption, which is intended to retain and attract manufacturers, applies to purchases of capital equipment made from July 1, 2014 through June 30, 2022 and reduces California state sales tax by 4.1875 percent on up to $200 million of a manufacturer's purchases. A company that takes advantage of the exemption could potentially save up to $8.375 million in sales taxes per year. Eligible purchases include basic manufacturing equipment as well as food processing and biotech R&D equipment.

Recommendations to Increase Access to Capital for Manufacturers in California

Institute a special tax credit for venture capital investments in small enterprises that manufacture products within the state.

California's concentration of venture capital investment has contributed to its strength as an innovation hub for advanced technologies and services, especially in relationship to computing and healthcare. In 2014, California-based companies received 56 percent of the $48 billion of venture capital investment in the US.[39] However, the types of enterprises that venture capital generally funds are an imperfect fit with manufacturing, as sectors such as advanced materials and biotechnology require larger capital outlays and longer times to exit than are usually funded through the venture capital model.[40]

To create a stronger market for investment in the state's manufacturing base, especially small manufacturers, California could employ a tax credit for investments made in the sector. At least 21 states offer income and business tax credits for angel investments;[41] these credits range from 15 percent of the investment in Colorado to 100 percent in Hawaii. Some states (Arizona, Ohio, and Maine) offer higher credits for investing in businesses that are located in targeted locales or that operate within a specific sector (nanotechnology in Wisconsin). A similar strategy in California can be tailored to investments in small manufacturers that produce at least a specified percentage of their products within the state.

Make manufacturers more aware of state-provided funding sources.

California has been able to lower overall costs for manufacturing capital expenditures by providing Industrial Development Bonds for project sponsors. However, only seven manufacturers used this financing mechanism between 2012 and 2014, with $32.5 million issued. Historically, loan reporting requirements and lengthy approval processes have tended to lower manufacturers' interest in applying for bond issuances. If the benefits of the program are marketed more aggressively through local economic development channels, a greater number of manufacturers will be encouraged to take advantage of low-cost capital when expanding or moving their operations.

Support the creation of local facilities housing manufacturing equipment that can be used for product prototyping and as a way to help small manufacturers conserve resources and move their products more quickly to market.

One of the key reasons that new product ideas fail to receive investments that would enable them to be manufactured at scale is the lack of a prototype. Prototyping can be costly for new companies that lack access to manufacturing tools, though organizations in California are beginning to provide these tools to entrepreneurs. For example, Prospect Silicon Valley, a nonprofit technology commercialization catalyst supported by the City of San Jose, assists emerging companies via its demonstration center, a $12 million, 23,000 square foot facility with industrial and lab space. There, companies are able to demonstrate new technological innovations in a real world setting, helping them bring their products to the market faster.

SPOTLIGHT

New Spaces for Manufacturing

Spaces that are zoned for industrial uses are especially scarce in dense urban areas, as many sites that were once used for producing goods have been converted to commercial or residential uses by cities looking to capture greater tax receipts. Building new industrial spaces can often be extremely expensive due to high urban land costs, and it can sometimes be met with significant community opposition. For these reasons, SFMade, a San Francisco non-profit that works to support manufacturing within the city, has developed a program to create affordable manufacturing spaces. Through the real estate development entity PlaceMade, SFMade is partnering with the city and private developers to create new industrial spaces.

The first of these projects is a 56,000 square foot "manufacturing foundry" that will house multiple industrial tenants in San Francisco's Potrero Hill neighborhood. The project is composed of three buildings, one of which will be used by SFMade to provide space to small, start-up manufacturers that otherwise would have to spend significant capital on workspaces. The other buildings will have ground floor industrial spaces with compatible office uses above.

SFMade is one many organizations catering to the burgeoning "maker movement" in the Bay Area and beyond. TechShop, an open-access makerspace with eight locations across the country (including three Bay Area locations), provides another example of the benefits of shared industrial space. It offers access to laser cutters, plastics and electronics labs, machine tools, a wood- and metal-working shop, a textiles department, and welding stations. It also provides comprehensive instruction in each area. TechShop's programs have helped aspiring entrepreneurs to build greater knowledge of manufacturing techniques, and they have provided a launching point through prototyping for numerous start-ups (including mobile payment platform provider Square, device case maker DODOcase, and book lamp manufacturer Lumio).

Universities are also offering up their facilities to allow manufacturers easy access to prototyping equipment. In Southern California, UC Irvine is home to the non-profit RapidTech, which is equipped with fifty 3D printing machines and other equipment that companies can use to quickly visualize and design a product. In addition to allowing small businesses the ability to use prototyping equipment, RapidTech also trains community college and university students in technical skills—helping to bridge the skills development gap between four-year universities and community colleges.

At UC Davis, Area 52—a new maker space—will offer machinery and co-working space for start-ups, with a particular focus on medical devices, agricultural technology, robotics, energy and aerospace. The 36,000 square foot facility, located close to campus, will provide wet labs, a fully equipped machine shop, a wind tunnel, a composites shop and a computer lab, with the goal of reducing the cost to start-ups of prototyping new products. Vocational courses will also be available for students seeking advanced manufacturing technology skills.

Address the Cost of Doing Business in California for Manufacturers

The high cost of operating a business in California is often cited as a reason why manufacturers choose to locate facilities in other states.[42] According to an August 2014 study by the California Foundation for Commerce & Education, California ranks 43rd of all US states in terms of general business costs, ranking in the bottom 10 in terms of the costs of taxes, litigation, energy, and labor.[43] The study also found that the average costs of auto manufacturing and machine shops in California are respectively 27 percent and 14 percent higher than the average for other western states.

While the cost of doing business in California can place a burden on some manufacturers, many companies continue to produce in California and many others are deciding to locate new facilities within the state. For high-value manufacturers, the state's large consumer demand, proximity to foreign markets, high-skilled talent, and network of universities and research centers often can offset the additional costs imposed by regulation and other state policies. However, manufacturers that are less integrated with the state's innovation economy are more likely to feel burdened by the state's regulatory environment.

Three areas of high cost for manufacturers in California are detailed below.

The Impact of Environmental Regulations on Manufacturers

The California Environmental Quality Act (CEQA) requires state and local agencies to identify significant environmental impacts of their actions and to avoid or mitigate those impacts. Most proposals for physical development in California are subject to CEQA, as the statute applies to all discretionary projects proposed or approved by a California public agency. This includes privately-funded projects such as those related to the expansion or new building of manufacturing facilities.

The environmental reviews that CEQA requires can be challenged in court by any group opposing the project (often for reasons that are not environmental in nature), adding time, cost, and legal complications to new projects. For example, Japanese light-rail manufacturer Kinkisharyo International almost scuttled plans to build a new facility in the Southern California city of Palmdale in 2014 due to a CEQA challenge from labor groups.[44] While the two sides eventually settled, the Kinkisharyo example highlights the unintended consequences that CEQA can have on manufacturing. Given the debilitating economic impacts that CEQA can have, reform measures continue to be a priority for many policymakers.

High Costs of Workers' Compensation in California

Workers' compensation premiums make up an average of 1.5 percent of manufacturers' total employee compensation costs in the US. (These costs include wages, paid leave, retirement and savings, and other legally required benefits.)[45] While a small overall cost, that percentage is much higher in California—at 3.5 percent of costs—as of January 2014.[46] As neighboring states such as Arizona, Oregon, and Nevada have workers' compensation premium rates well below the national median, the added costs of operating in California can deter some manufacturers from expanding their in-state workforces. However, this is less the case for high-value producers where capital costs far outweigh the costs for labor.

California's high workers' compensation premiums are attributable to higher-than-average utilization. California's rate of work injury claims per 1,000 workers is 46 percent higher than the national average. While reduced claim frequency has been driving rates lower across the country, in California, claim frequency increases of 3.2 percent in 2012 and 3.9 percent in 2013 have been pushing expenses higher.[47]

California's system is also more expensive to run because of complex administrative features, which were the target of Senate Bill 863, passed in 2012. The legislation aims to reduce "friction" in the system and generate savings to enable employer premium reductions. To date, potential savings, estimated at $200 million annually (or 1.2 percent of total system costs) have been eclipsed by claim payment increases.[48]

Limited Land Availability for Industrial Use in Urban Areas

In California's two leading manufacturing regions, the San Francisco Bay Area and Los Angeles, manufacturing development is being constrained by a lack of land availability as well as by a scarcity of vacant manufacturing facilities that could be repurposed for alternative uses. Bay Area industrial vacancy rates are currently approaching the historic low levels set in the late 1990s during the dot-com boom. Larger manufacturers are beginning to look outside of the immediate Bay Area to markets in San Joaquin County where available options and rental rates are more favorable.

In Los Angeles, a manufacturing base that was located within the central urban core has continually been pushed to outlying areas as land use policies have shifted. The City of Los Angeles has only 8 percent of its total land base zoned for industrial uses; however, nearly 30 percent of this land has already been redeployed for commercial and residential uses. Competition for industrially-zoned land in Los Angeles remains high as evidenced by its 3 percent industrial vacancy rate, the lowest of any metropolitan area in the state.

Industrial land use policies can alleviate some of the land availability issues that manufacturers encounter in California. Industrial zone policies date back to the 1980s when Chicago, New York City, and Portland created planned manufacturing districts in order to protect industrial land that was being encroached upon by residential uses. Manufacturers in these districts were afforded special rights, such as expedited permitting for building expansion and eligibility for special financing options, and they received benefits, such as city-provided infrastructure spending on new bridges and streets and on improved transit and transportation options to support employment.

More recently, New York City created 15 Industrial Business Zones in 2006. These zones were intended to foster real estate support for manufacturers by limiting the potential for residential rezoning, along with tax credits and zone-specific planning efforts supporting business relocation. Since that time, a large amount of land in these industrial safe havens has been converted to commercial uses—prompting the New York City Council to reevaluate its land use policies for manufacturing.

Recommendations to Reduce the Cost of Doing Business in California

Create a more targeted mechanism for CEQA challenges to environmental reviews.

Limiting windows for CEQA challenges would be a first step toward changing CEQA from the barrier that it often can be to the environmental tool it was intended to be. In the 40 years since CEQA was passed, Congress and the California Legislature have adopted more than 120 laws to protect environmental quality in many of the same areas required to be mitigated under CEQA. These include laws like the Clean Air Act, the Clean Water Act, and the Endangered Species Act at the federal level, as well as greenhouse gas emissions reduction standards (Assembly Bill 32) and a requirement to prioritize transportation projects in preferred growth areas (Senate Bill 375) at the state level. CEQA reform should take into account the environmental standards that these laws seek to meet while introducing increased accountability, transparency, consistency, and timeliness to CEQA processes.

Identify areas of manufacturing concentration and designate those areas for prioritization in land use planning.

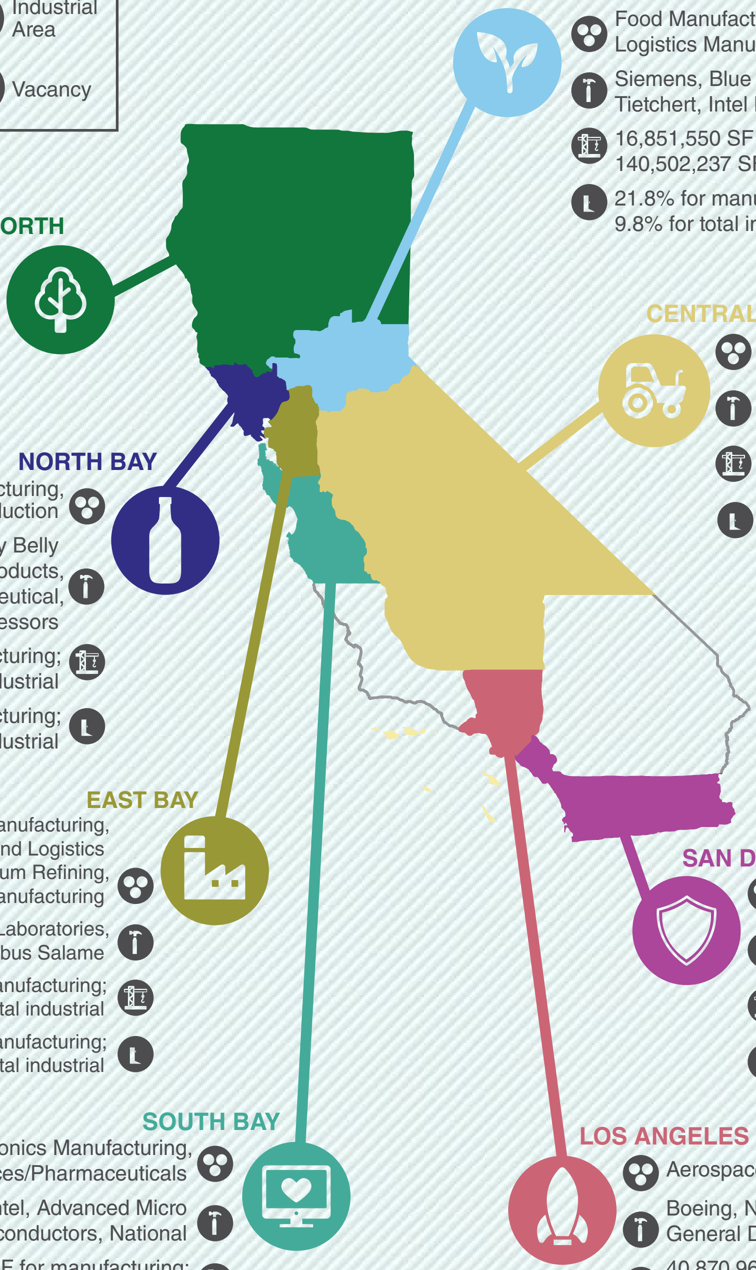
By the creation of special designations, such as Industrial Priority Corridors, cities across California can preserve urban industrial bases, and manufacturers can have greater certainty in making long-term real estate investments. Additionally, cities should consider balancing the competing needs of residential and commercial uses while prioritizing infrastructure investments in these areas. For example, zoning that promotes and requires greater density and mixed, compatible uses (e.g., commercial and industrial space alongside residential) can spur the creation of creative corridors for the advanced manufacturing economy. As advanced manufacturers move toward smaller-scale custom manufacturing with new technologies, the preconception of manufacturers needing large parcels of land to house buildings with smokestacks and high noise levels no longer holds. Instead, policies should be explored to allow manufacturing activities to coexist with other uses in populated areas.

INSIGHT

Industrial Land Use in California

Greg Matter, *Jones Lang LaSalle*

Cluster Type
Industrial Area
Largest Manufacturers
Vacancy



SACRAMENTO

Food Manufacturing, Transportation and Logistics Manufacturing, Construction Materials

Siemens, Blue Diamond Growers, Aerojet, Tietchert, Intel Materials Materials

16,851,550 SF for manufacturing;
140,502,237 SF total industrial

21.8% for manufacturing;
9.8% for total industrial

FAR NORTH

Food Manufacturing, Timber Products

Sierra Pacific Industries

Not an established market

N/A

CENTRAL VALLEY

Food Manufacturing Materials

Foster Farms, Kelloggs, Kraft Foods, General Mills

17,849,037 SF for manufacturing;
106,230,114 SF total industrial

15.5% for manufacturing
6.7% for total industrial

NORTH BAY

Food Manufacturing, Wine Production

Anheuser-Busch, Clorox, Jelly Belly Candy Company, Bell Products, BioMarin Pharmaceutical, Petaluma Poultry Processors

24,654,928 SF for manufacturing;
74,257,728 SF total industrial

3.1% for manufacturing;
8.1% for total industrial

EAST BAY

Heavy Industrial Manufacturing, Transportation and Logistics Manufacturing, Petroleum Refining, Household Goods Manufacturing

Chevron, Clorox, Bio-Rad Laboratories, Tesla, Annabelle Candy, Columbus Salame

24,189,569 SF for manufacturing;
110,324,539 SF total industrial

7.8% for manufacturing;
5.8% for total industrial

SAN DIEGO

Biotech/Medical

Life Technologies Corp, Neurocrine Biosciences

49,200,297 SF for manufacturing;
128,099,712 SF total industrial

9.0% for manufacturing;
5.9% for total industrial

SOUTH BAY

Computer & Electronics Manufacturing, Biotech/Medical Devices/Pharmaceuticals

Apple, Google, Microsoft, Intel, Advanced Micro Devices, Cisco, Marvell Semiconductors, National

24,654,928 SF for manufacturing;
74,257,728 SF total industrial

3.1% for manufacturing;
8.1% for total industrial

LOS ANGELES

Aerospace, Biotech/Medical

Boeing, Northrup Grumman, Lockheed Martin, General Dynamics, Honeywell, Amgen

40,870,964 SF for manufacturing;
780,456,056 SF total industrial

4% for manufacturing;
3% for total industrial

Note: The eight industrial land use regions do not directly correspond with the eight manufacturing regional clusters analyzed in Part Two because the industrial land use map is based upon proprietary data provided by Jones Lang LaSalle.

PART
Two

California manufacturing trends can be seen in eight regional clusters.

California Manufacturing Regional Clusters Analysis

Los Angeles Area

The Los Angeles Area—defined as Los Angeles, Riverside, San Bernardino, and Ventura Counties—is California's largest manufacturing hub. With 478,919 manufacturing jobs, the region accounted for 38.5 percent of the state's manufacturing employment and 8.4 percent of the region's total employment in 2014. Much of this activity is concentrated in the corridor between Los Angeles and Long Beach. These two cities host two of the US's top four ports (measured by total foreign trade), together totaling nearly $400 billion in 2014 import and export value.[49]

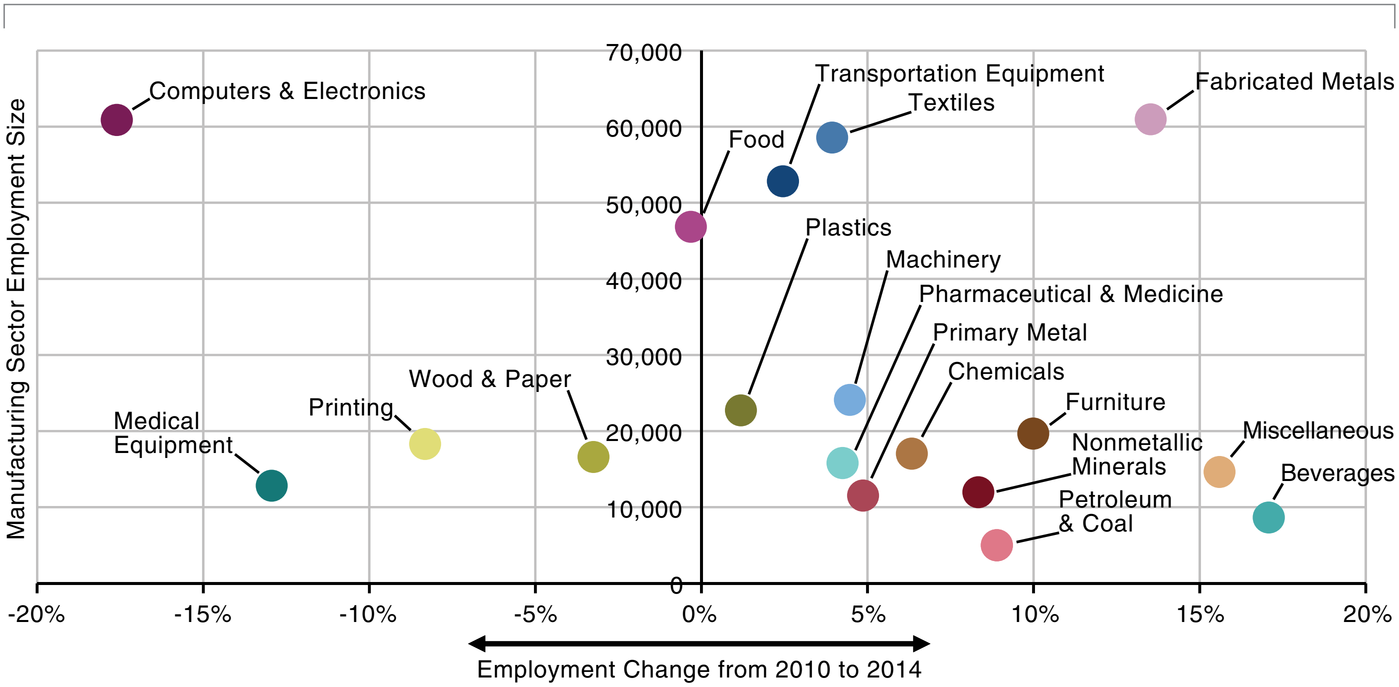
In terms of employment, the Los Angeles Area's leading manufacturing sector is Fabricated Metal Product Manufacturing. With 60,962 jobs in 2014, this sector constituted 12.7 percent of the region's manufacturing employment base. Other sectors that were not far behind in employment size include Apparel, Textile, & Leather Manufacturing, Computer & Electronic Product Manufacturing, Food Manufacturing, and Transportation Equipment Manufacturing.

The distribution of establishments across manufacturing sectors in the Los Angeles Area has remained fairly stable since 1990. Large declines took place between 1990 and 2014 in Furniture & Related Product Manufacturing—down 49.1 percent, Printing & Related Support Activities—down 48.3 percent, and Transportation Equipment Manufacturing (principally aerospace)—down 31.7 percent. On the opposite end of the spectrum during the same period, the number of establishments in Beverage Manufacturing and Food Manufacturing increased by 62.4 and 3.7 percent respectively.

In the 2010–2014 time period, the Los Angeles Area manufacturing sector with the fastest growing employment was Beverage Manufacturing (+17.1 percent). Additional sectors that have led job growth since 2010 include Miscellaneous Manufacturing (+15.6 percent), Fabricated Metal Product Manufacturing (+13.5 percent), and Furniture & Related Product Manufacturing (+10.0 percent). However, over the long term (1990–2014) and reflective of nationwide trends, each of those three additional sectors experienced overall job losses in the Los Angeles Area, so the jobs added since 2010 represent a start at recovery and not a net gain.

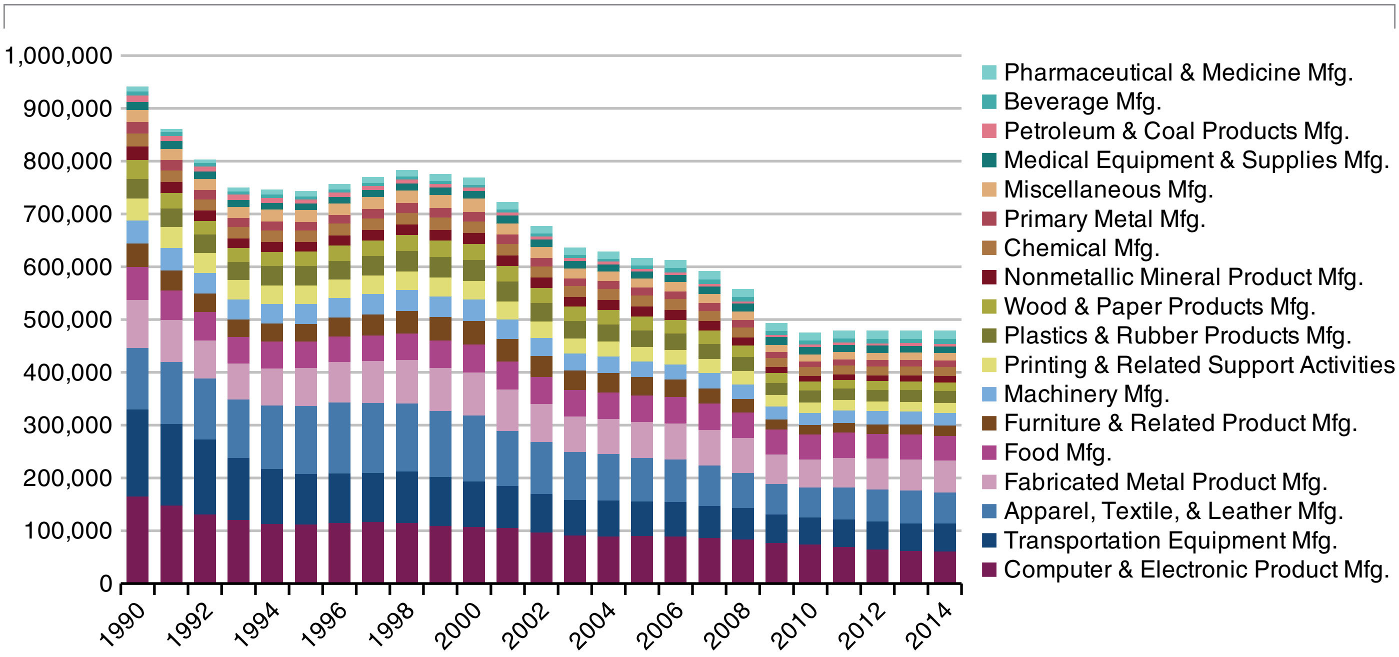
In contrast, Beverage Manufacturing had 1.9 percent more employment in 2014 than in 1990, and Pharmaceutical & Medicine Manufacturing had 89.3 percent more jobs in 2014 than in 1990, having experienced job growth throughout the 1990–2014 period rather than a surge in growth since 2010.

Los Angeles Area Manufacturing Change by Sector, 2010–2014



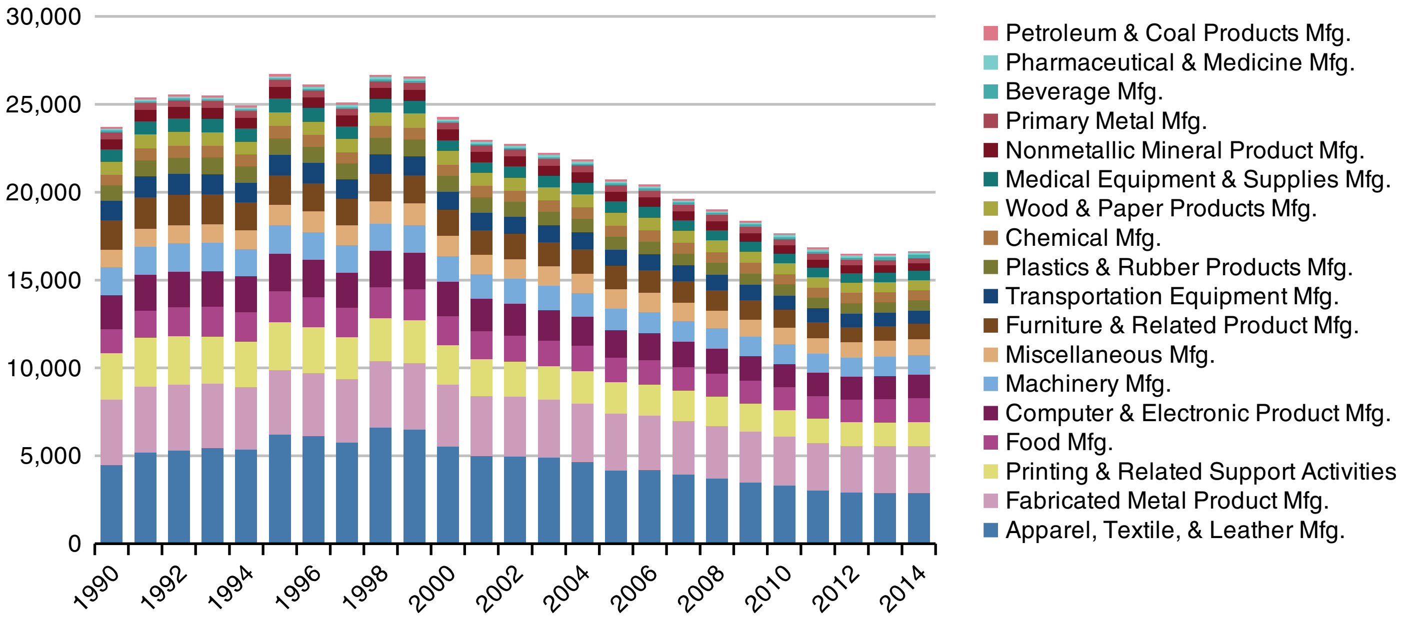
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Los Angeles Area Manufacturing Employment by Sector, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Los Angeles Area Manufacturing Establishments by Sector, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Bay Area

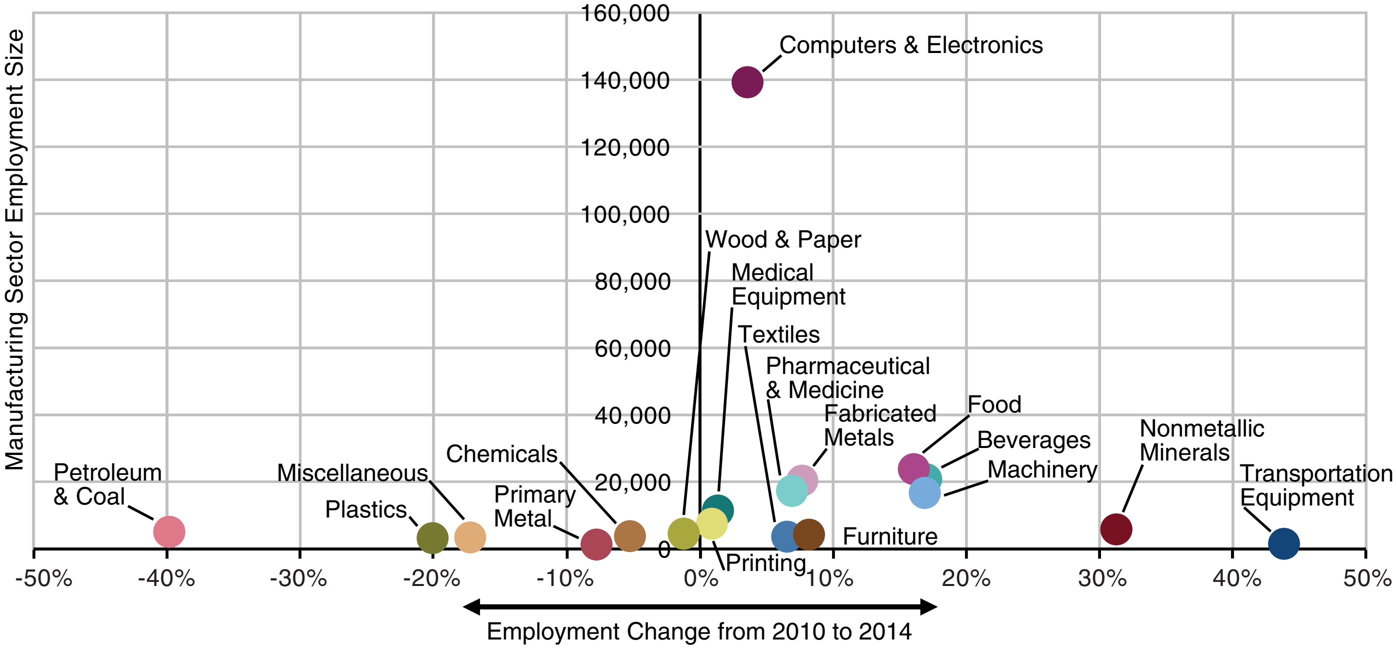
The Bay Area—defined as Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma Counties—is a leading technology hub. The region's rich innovation ecosystem is based on a high-skilled workforce, world-class universities and research labs, robust capital investment platforms and dense networks that enable the movement of people and ideas. Throughout the development of its innovation economy, the co-location of R&D and production has been a source of strength, as the seamless collaboration between engineering production teams could speed the iterative process of innovation. After the loss of semiconductor fabs and other production facilities in the 1990s and 2000s, manufacturing in the region is refinding its roots.

Manufacturing as a whole accounted for 8.4 percent of Bay Area employment in 2014. Although the Bay Area is one of the most expensive regions of the state, many manufacturers are there because they are working closely with the region's technology companies. Not only are new, cutting edge products developed in the region, but new tools for production are also developed there. Localized supply chains that have formed around subsectors, such as energy-efficient lighting, healthcare devices, and automotive vehicles, have supported the growth of manufacturing and have enabled high-value production to occur in close proximity to research activities.

In 2014, the Bay Area's 293,847 manufacturing jobs made up 23.6 percent of manufacturing employment in California. These jobs are heavily concentrated in the Computer & Electronic Products Manufacturing sector, which constituted 47.4 percent of the Bay Area's manufacturing employment with 139,271 jobs in 2014.

The Computer & Electronic Products Manufacturing sector also accounted for 19.1 percent of Bay Area

Bay Area Manufacturing Employment Change by Sector, 2010–2014



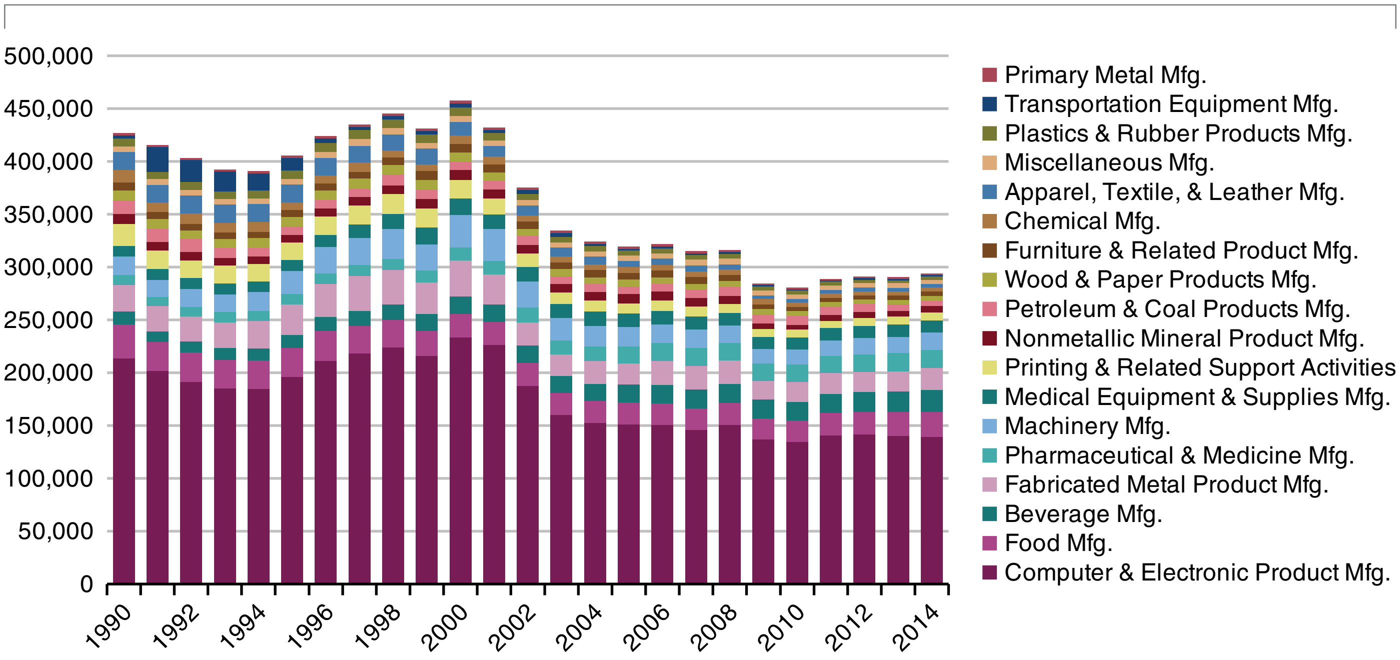
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

manufacturing establishments in 2014—the largest share. Many of these firms are clustered in the corridors between San Francisco, Santa Clara and Oakland. Establishments such as Cisco Systems, Intel, Oracle, and Advanced Micro Devices are large employers.

In the 2010–2014 time period, the Bay Area manufacturing sector with the fastest growing employment was Transportation Equipment Manufacturing, although it remained a very small portion of overall manufacturing employment in the region. This sector's accelerated employment change can be largely attributed to Tesla's emergence as a leader in electric vehicle production and to the cluster of suppliers that has formed around its Fremont factory.

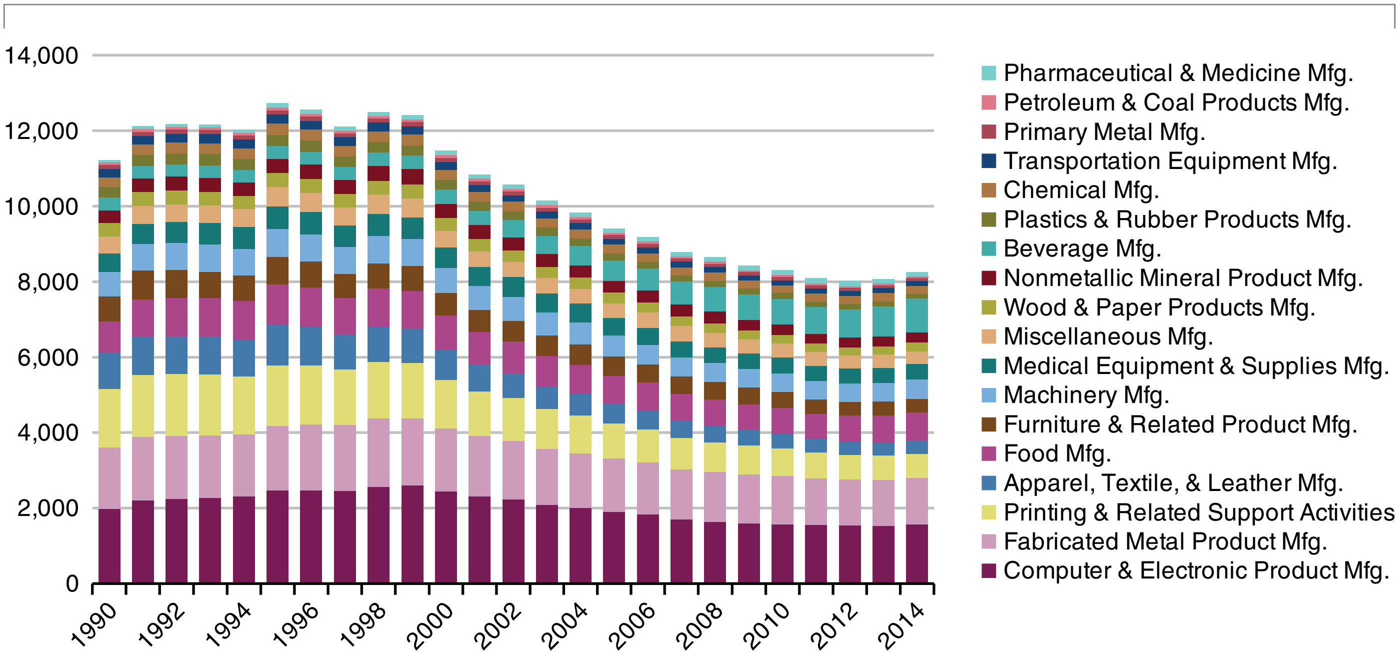
Measured by overall number of jobs, the five largest Bay Area manufacturing sectors all experienced job growth between 2010 and 2014: Computer & Electronic Product Manufacturing grew by 3.6 percent (adding 4,797 jobs); Food Manufacturing increased by 16.1 percent (adding 3,292 jobs); Beverage Manufacturing expanded by 17.0 percent (adding 3,019 jobs); Fabricated Metal Product Manufacturing grew by 7.7 percent (adding 1,451 jobs); and Machinery Manufacturing increased by 16.9 percent (adding 2,413 jobs). Beverage Manufacturing is the only one of these five sectors that did not experience employment contraction between 1990 and 2014 and therefore achieved a net gain in jobs over the long term.

Bay Area Manufacturing Employment by Sector, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Bay Area Manufacturing Establishments by Sector, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Orange County

Among the eight California regions defined in this analysis, Orange County ranks third in manufacturing employment, with 141,810 manufacturing jobs in 2014. It also has the highest concentration of manufacturing employment in the state, with manufacturing accounting for 10.0 percent of the region's employment.

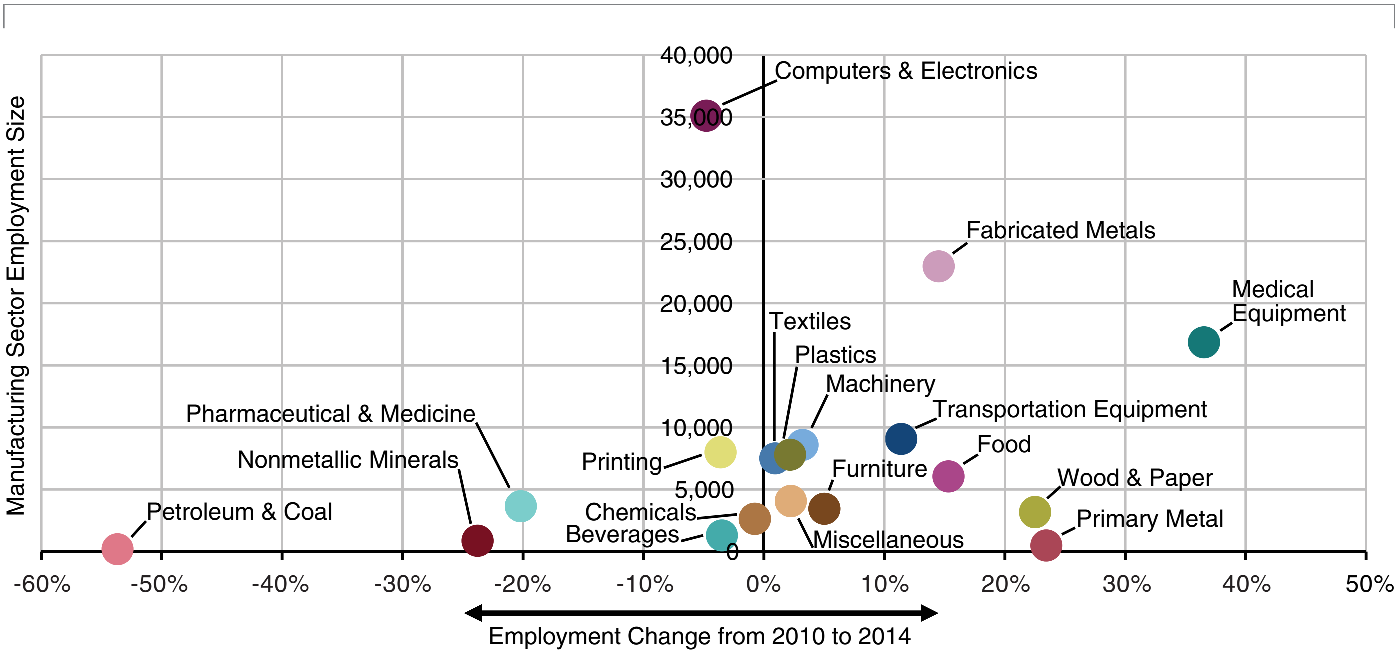
Orange County's Computer & Electronic Product Manufacturing sector has the highest manufacturing employment level, with 35,099 jobs making up 24.8 percent of overall manufacturing employment in the region in 2014. However, much like other California regions, Orange County's employment in Computer & Electronic Product Manufacturing has fallen over time, down 1,761 jobs since 2010 and 35,580 jobs since 1990.

Aside from computer-related manufacturing, Fabricated Metal Product Manufacturing and Medical Equipment & Supplies Manufacturing provide significant Orange County employment, with 22,976 jobs and 16,854 jobs in 2014, respectively.

In the recent time period between 2010 and 2014, the Orange County sectors with the greatest job growth have been Medical Equipment & Supplies Manufacturing (+36.5 percent), Primary Metal Manufacturing (+ 23.4 percent), and Wood & Paper Products Manufacturing (+22.5 percent).

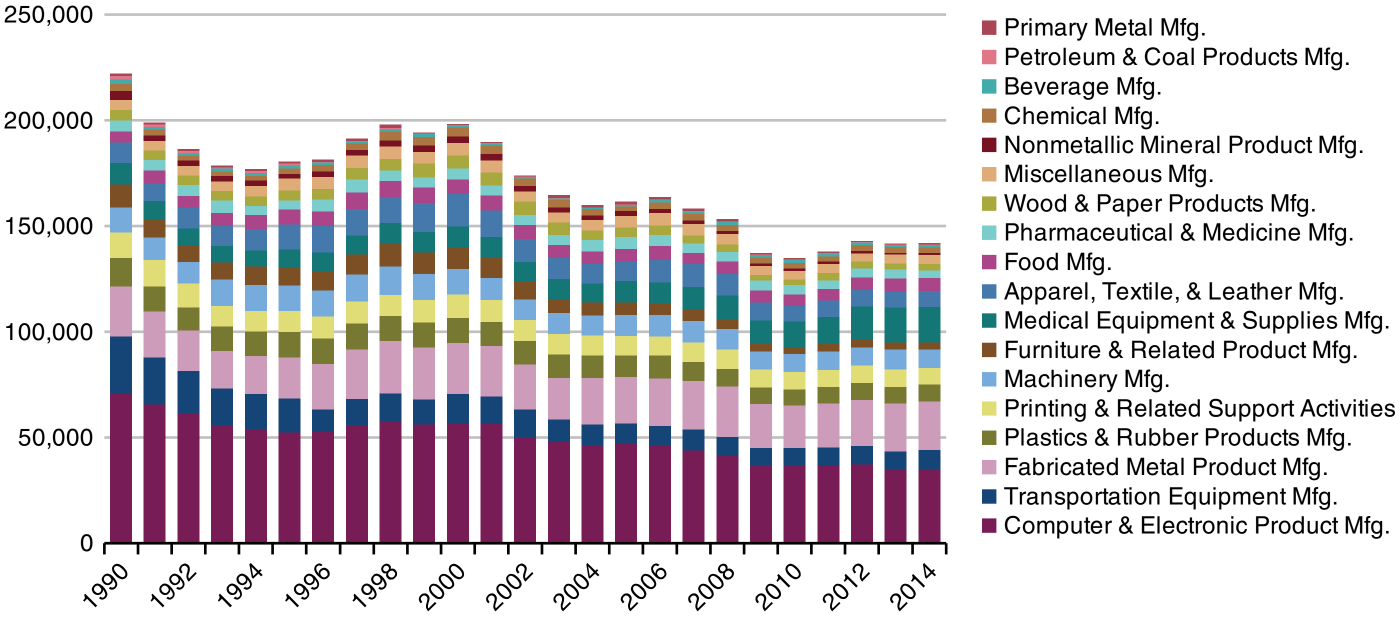
Over the long term (1990–2014), Medical Equipment & Supplies Manufacturing has also grown significantly, expanding by 64.1 percent since 1990. These jobs were added primarily in companies such as heart valve maker Edwards Lifesciences Corporation, healthcare product company Covidien, and Alcon Surgical.

Orange County Manufacturing Employment Change by Sector, 2010–2014



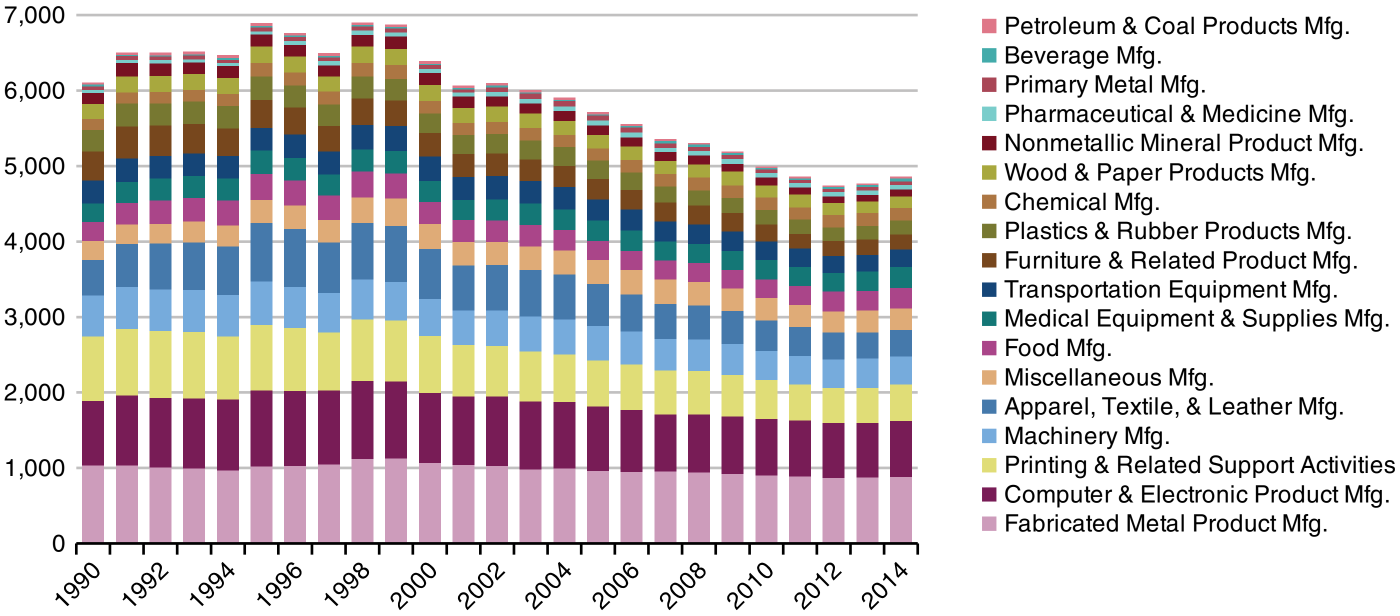
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Orange County Manufacturing Employment by Sector, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Orange County Manufacturing Establishments by Sector, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

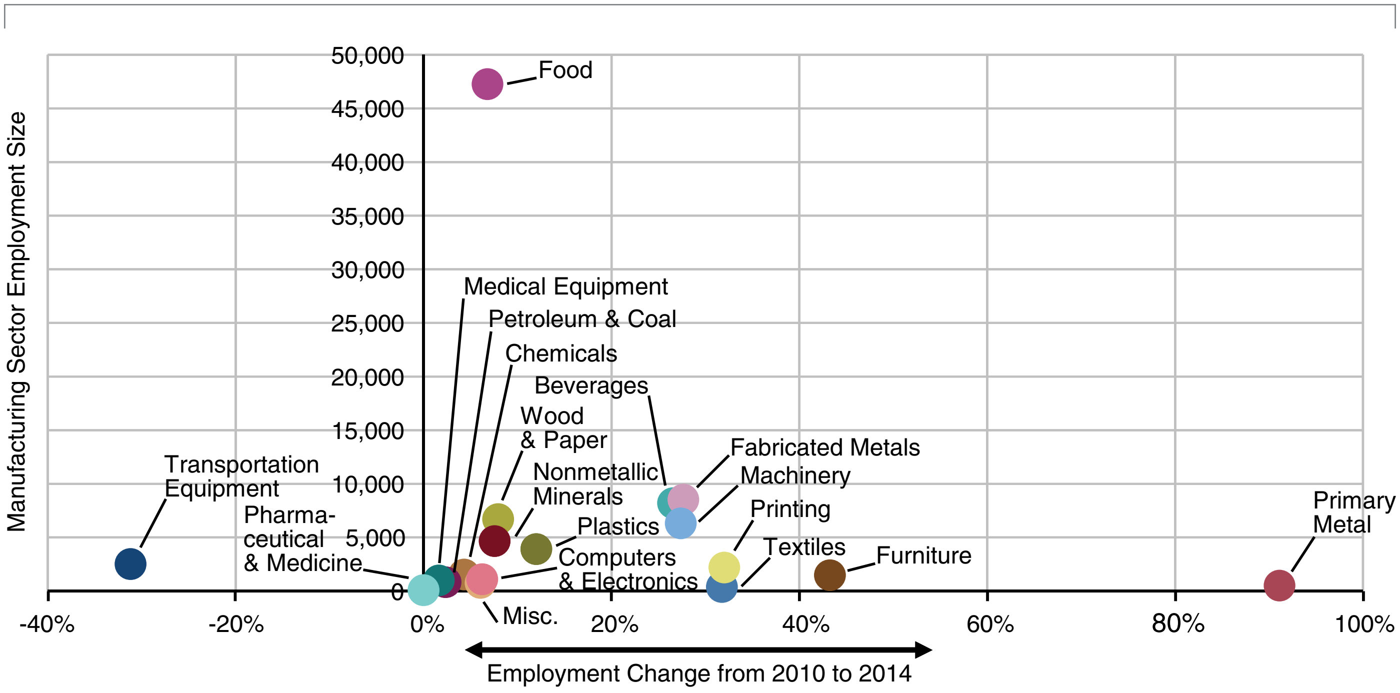
Central Valley

California's Central Valley—consisting of Alpine, Amador, Calaveras, Fresno, Inyo, Kern, Kings, Madera, Mariposa, Merced, Mono, San Joaquin, Stanislaus, Tulare, and Tuolumne Counties—is the heartland of the state's food production sector. Clustered around the cities of Bakersfield, Fresno, Modesto, and Stockton, the Central Valley's manufacturing sectors provided 98,038 jobs in 2014, and manufacturing accounted for 6.9 percent of employment in the region. The Central Valley, unlike other parts of California, does not have a major electronics sector.

Food Manufacturing accounted for 48.2 percent of manufacturing employment and 20.8 percent of manufacturing establishments in the region in 2014. Employment in this sector grew by 8.4 percent between 1990 and 2014 and by 6.8 percent between 2010 and 2014. The largest food companies in the Central Valley include meat processing firms Foster Farms and Zacky Farms, ethnic food producer Ruiz Foods, tomato processor Kagome, and vegetable and fruit processor ConAgra Foods.

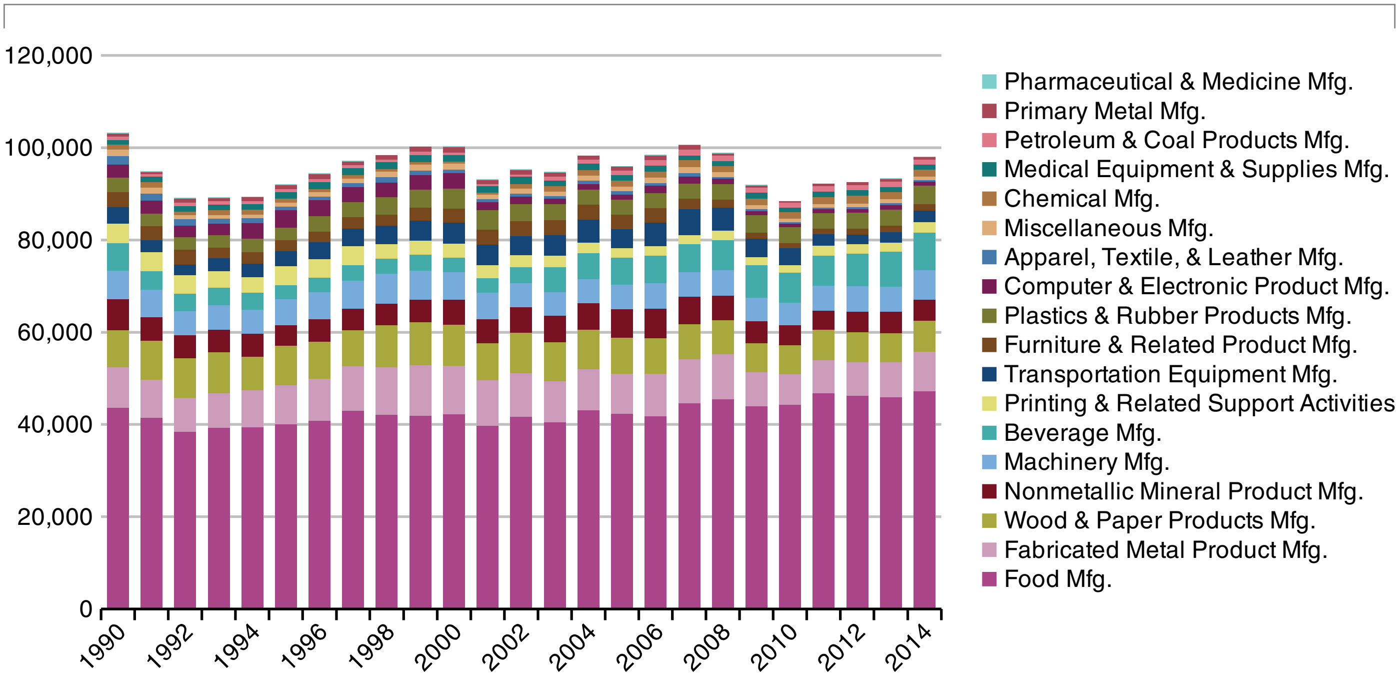
Aside from Food Manufacturing, Central Valley manufacturing employment numbers have shown strengths in Fabricated Metal Product Manufacturing, Beverage Manufacturing, Wood & Paper Products Manufacturing and Machinery Manufacturing. Sectors that have experienced the most rapid growth between 2010 and 2014 include Primary Metal Manufacturing and Furniture & Related Product Manufacturing.

Central Valley Manufacturing Employment Change by Sector, 2010–2014



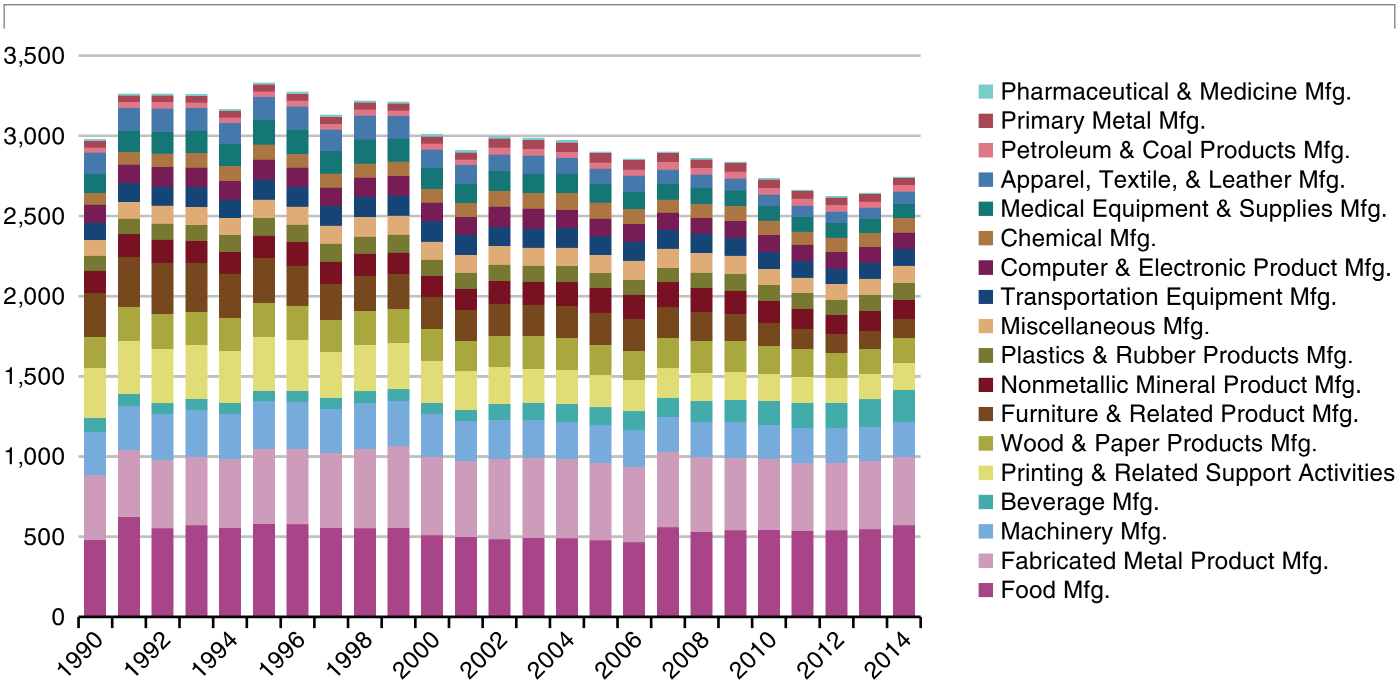
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Central Valley Manufacturing Employment by Sector, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Central Valley Manufacturing Establishments by Sector, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

San Diego Area

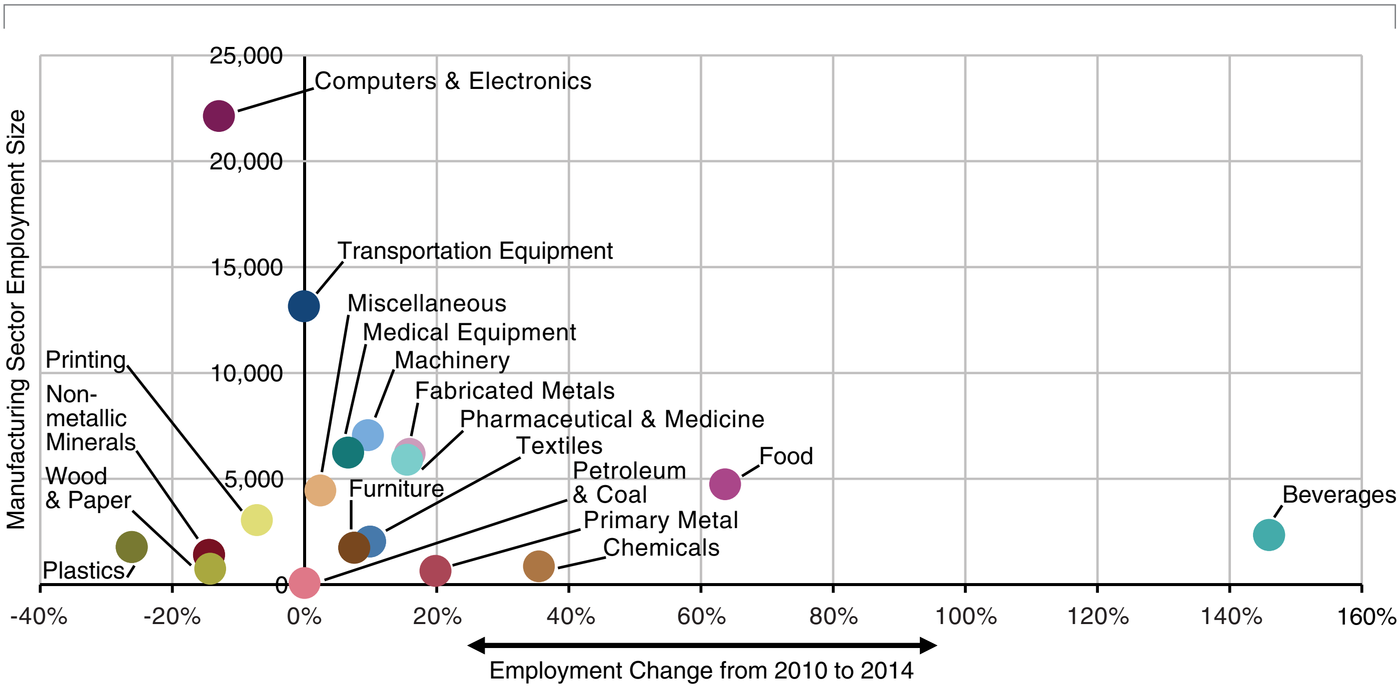
Consisting of San Diego and Imperial Counties, the San Diego Area hosts the largest regional military presence in the US and is home to the Navy's largest West Coast base. Given the region's military assets and large number of veterans, the defense industry accounts for one out of every four San Diego Area jobs. Manufacturing provided 6.2 percent of the region's employment in 2014. With aerospace and defense as its base, advanced manufacturing produces 23 percent of the San Diego Area's gross regional product.[50] Much of this activity comes from small manufacturers.

The San Diego Area offers unique workforce and geographic characteristics that attract manufacturers to the region. Military veterans are often well prepared for manufacturing roles when they return to the civilian workforce. San Diego's close proximity to machine shops in Mexico that can take advantage of low labor costs has allowed for the formation of cross-border supply chains. Life sciences research taking place at UC San Diego and the Salk Institute for Biological Studies has also created a strong cluster of biotechnology and pharmaceutical companies in the region.

Of the 84,615 manufacturing jobs in the San Diego Area in 2014, a large portion are defense-related. This is particularly true in the region's leading sector, Computer & Electronic Product Manufacturing, which made up 26.2 percent of manufacturing employment with 22,134 jobs in 2014. Among the largest employers in the sector are aerospace and defense companies Lockheed Martin, Northrup Grumman, and BAE Systems.

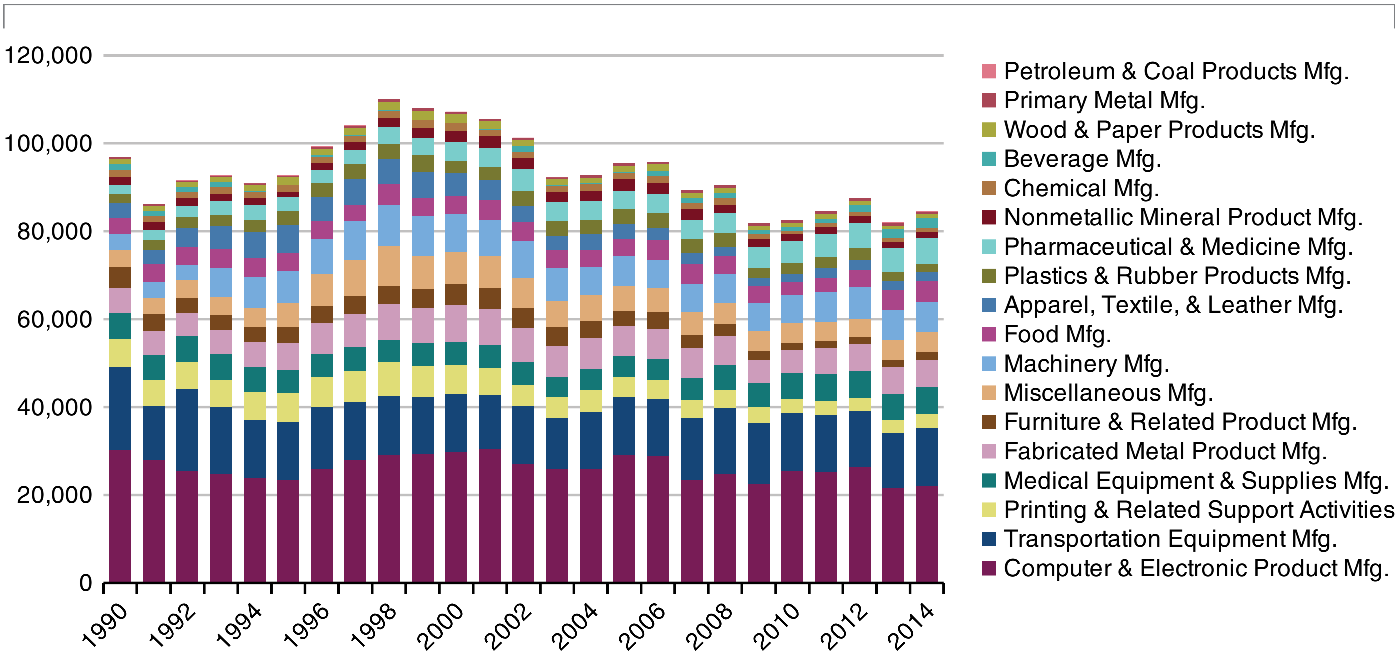
The sectors with the fastest growing employment have been Beverage Manufacturing and Food Manufacturing. Although Beverage Manufacturing lost jobs between 1990 and 2010, it experienced and a robust 146.0 percent employment increase between 2010 and 2014, achieving a 2014 total of 2,349 jobs (slightly over 1,000 more jobs than it had in 1990). Food Manufacturing showed a similar pattern with job losses between 1990 and 2010, followed by a 63.6 percent employment increase between 2010 and 2014, achieving a 2014 total of 4,744 jobs (slightly over 1,100 more jobs than it had in 1990).

San Diego Area Manufacturing Employment Change by Sector, 2010–2014



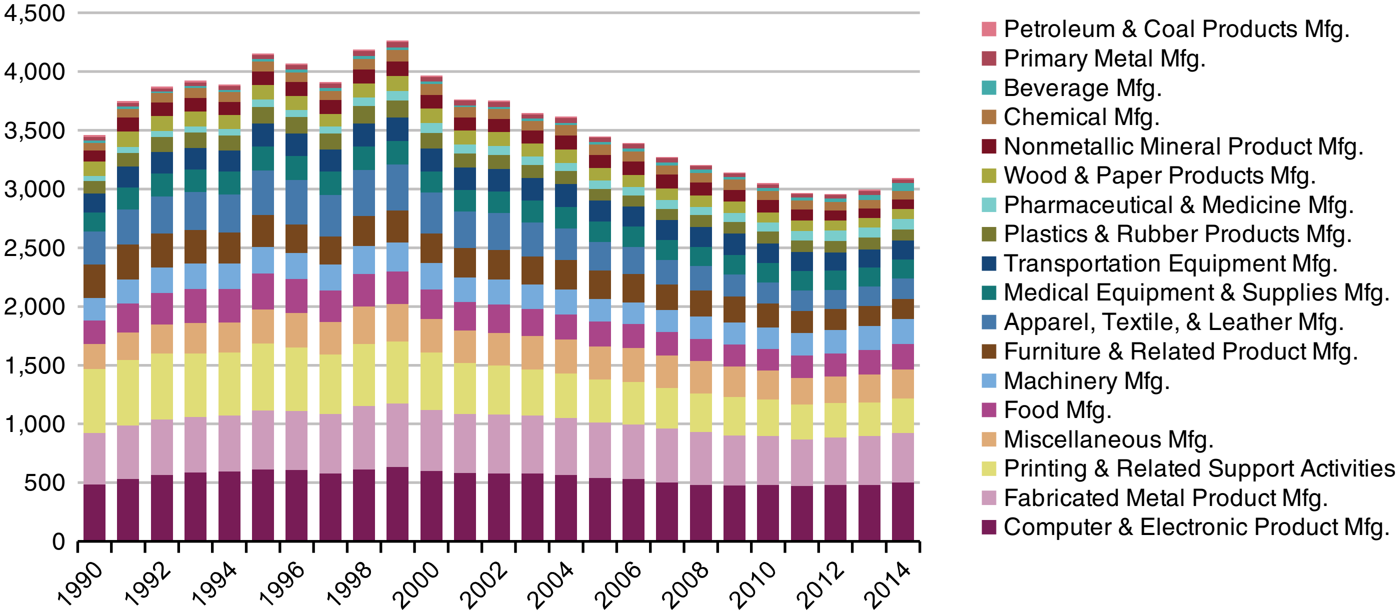
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

San Diego Area Manufacturing Employment by Sector, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

San Diego Area Manufacturing Establishments by Sector, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Central Coast

The Central Coast region consists of Monterey, San Benito, San Luis Obispo, Santa Barbara, and Santa Cruz Counties. Manufacturing in the region is largely tied to agriculture, but with more specialized products than manufacturing in the Central Valley. High-value products, such as lettuce, artichokes, and asparagus, are grown and processed in the region, and the Central Coast is also home to manufacturers specializing in agricultural field equipment and packaging. In 2014, the Central Coast's manufacturing sectors provided 23,460 jobs, and manufacturing accounted for 4.1 percent of jobs in the region.

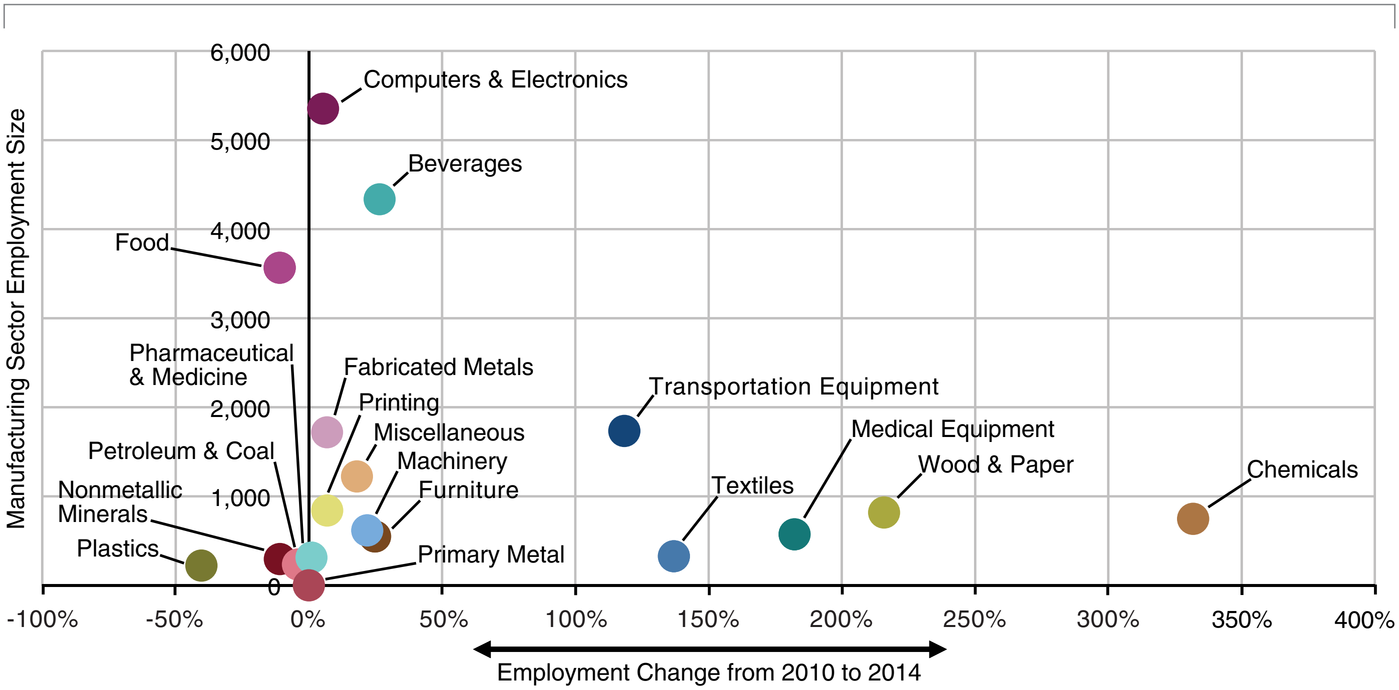
In addition to agriculture-related companies, the Central Coast has many manufacturers that are small in size but produce niche products at a high margin. In the Santa Cruz area, specialty makers of electric-powered motorcycles, surfboards, and skateboards are world leaders in their respective fields. In the Monterey area, marine-related manufacturing supports marine research that is conducted in Monterey Bay. Further south, San Luis Obispo County is well known for its wine and beverage industries, while Santa Barbara County has a growing Computer & Electronic Product Manufacturing sector, which is closely linked to technology commercialization programs at UC Santa Barbara.

Measured by employment, the three largest manufacturing sectors in the Central Coast region are Computer & Electronic Product Manufacturing, Beverage Manufacturing, and Food Manufacturing. Together these three sectors account for 56.5 percent of manufacturing employment in the region.

In the 2010–2014 time period, strong employment growth occurred across a range of manufacturing sectors in the Central Coast region. The fastest growing sectors were Chemical Manufacturing (excluding Pharmaceutical & Medicine Manufacturing), which increased by 331.8 percent (to a 2014 total of 747 jobs), and Wood & Paper Products Manufacturing, which grew by 215.8 percent (to a 2014 total of 818 jobs). While both of these sectors experienced job losses in a few of the years between 1990 and 2014, their overall growth experiences both resulted in 2014 total job numbers noticeably higher than their employment numbers for 1990 (170 and 504, respectively). Robust job growth between 2010 and 2014 also occurred in Medical Equipment & Supplies Manufacturing (+182.3 percent), Apparel, Textile, & Leather Manufacturing (+137.0 percent), and Transportation Equipment Manufacturing (+118.4 percent). In those three sectors, however, the jobs gained represent a start at recovery from job losses over the long term (1990–2014) rather than net gains.

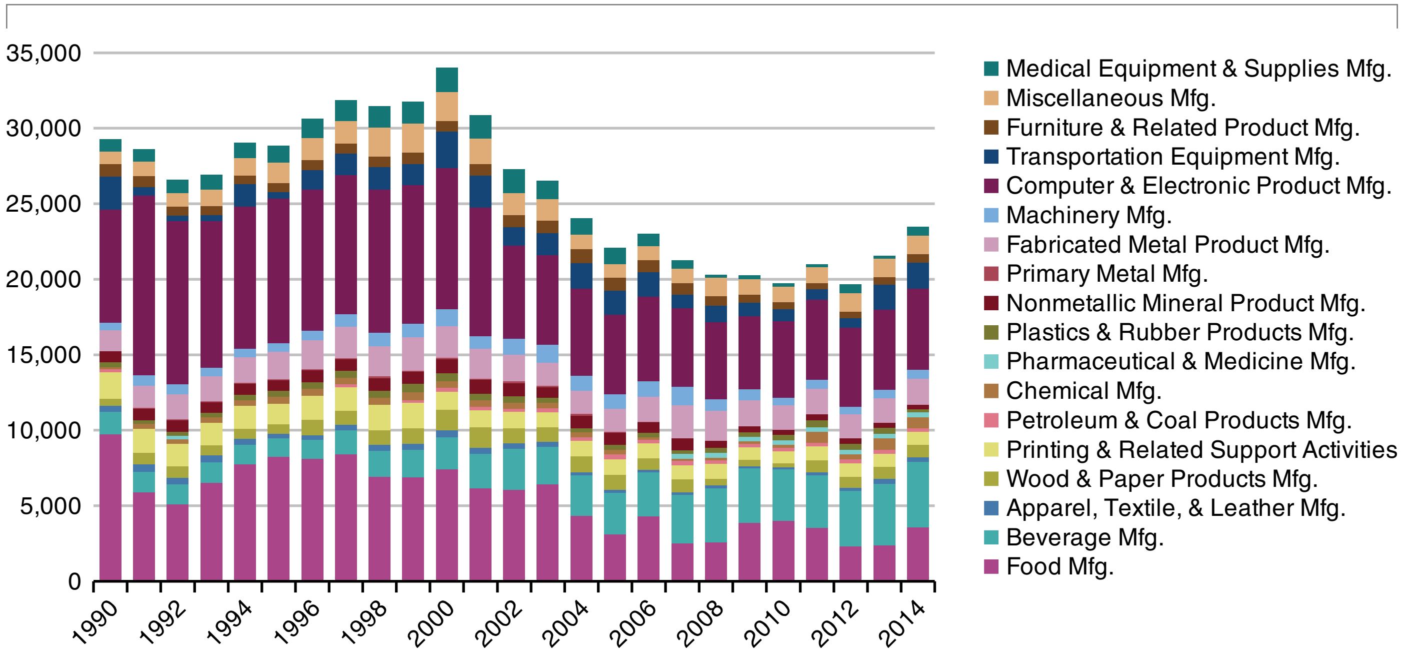
For the three Central Coast manufacturing sectors with the largest number of jobs overall, the growth experience was mixed. Computer & Electronic Product Manufacturing contracted by 28.4 percent over the long-term period from 1990 to 2014, and its 5.3 percent job growth between 2010 and 2014 did not allow it to fully bounce back. In contrast, the Beverage Manufacturing sector did not experience contraction during the long-term period, and in the 2010–2014 time period it expanded by 26.5 percent, adding over 900 jobs. Although maintaining its status as the third largest Central Coast manufacturing sector, measured by employment, the Food Manufacturing sector experienced only employment contraction, both in the long-term period (-63.4 percent) and in the recent time period since 2010 (-11.0 percent).

Central Coast Manufacturing Employment Change by Sector, 2010–2014



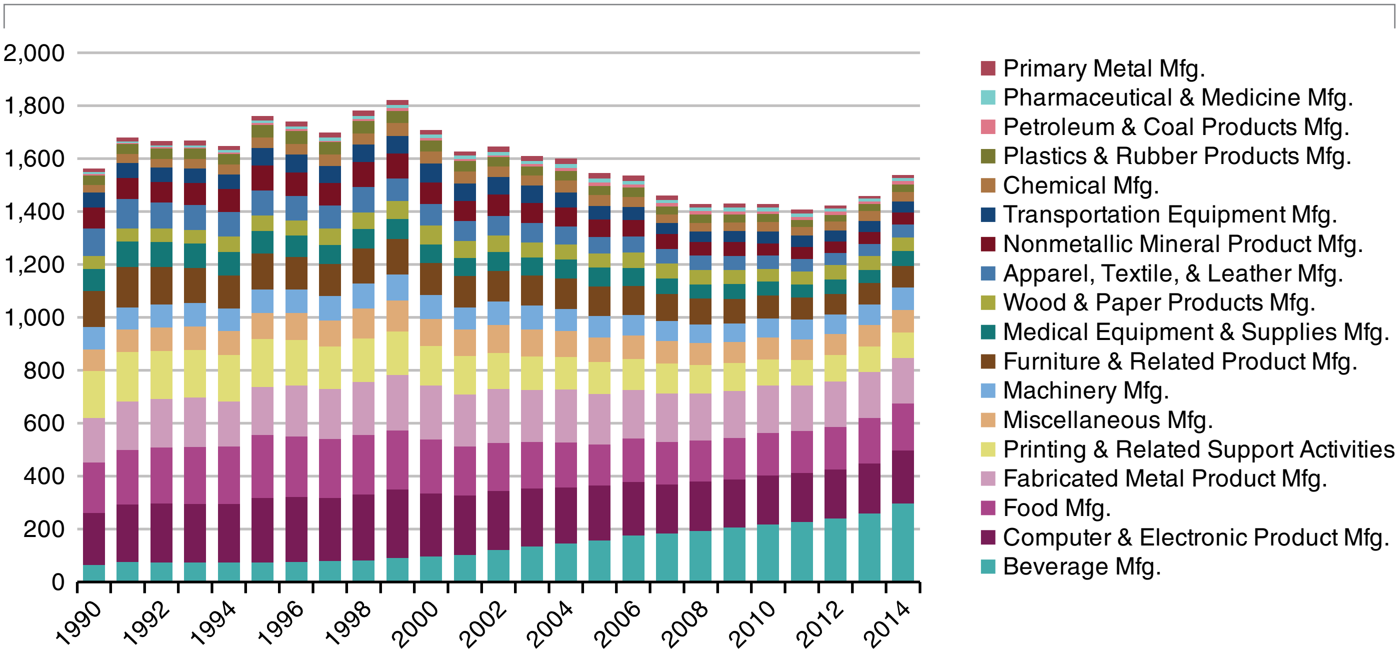
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Central Coast Manufacturing Employment by Sector, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Central Coast Manufacturing Establishments by Sector, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD

Analysis: Bay Area Council Economic Institute

Sacramento Area

Located close to the Bay Area's technology hub and the Central Valley's agricultural strength, the Sacramento Area has carved out a manufacturing niche at the convergence of technology and agriculture. The Sacramento Area is defined as El Dorado, Placer, Sacramento, Sutter, and Yolo Counties. While accounting for only 2.4 percent of jobs in the region—the lowest regional share in the state—manufacturing in the Sacramento Area has seen strong employment growth.

Bayer CropScience opened a new biologics lab in West Sacramento in 2014 to produce seed prototypes and new crop protectants. Additionally, the area's proximity to the Food Science and Technology Division at UC Davis makes it attractive for high-value-added manufacturers, such as those involved in agricultural genetics, advanced food processing, and food storage and safety.

The region's advantages include high-quality water for food production, easy access to fresh food inputs, affordable energy from a municipally-owned utility, availability of industrial space, and proximity to a local market of consumers who value high-quality food products. These offerings have made the Sacramento Area very attractive for both domestic and international food producers. Access to the Bay Area's technology and investment community is another plus.

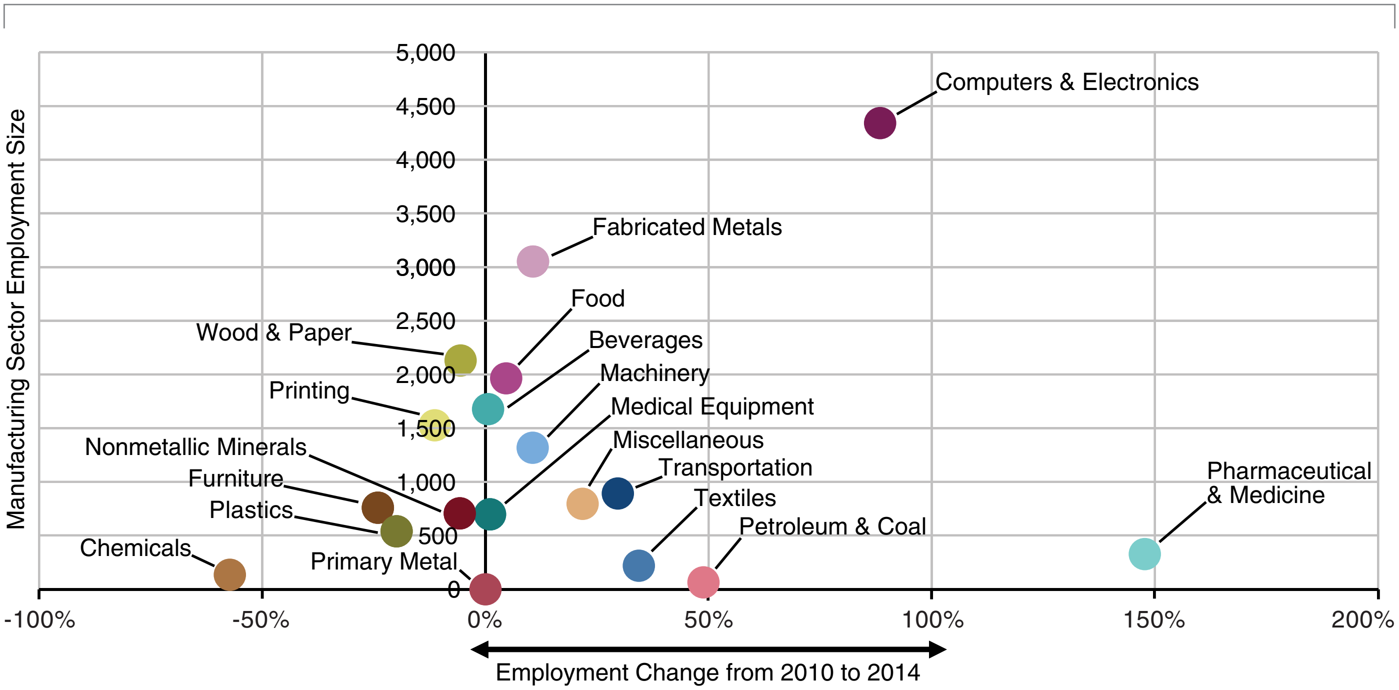
In 2014, the manufacturing sector in the Sacramento Area provided 21,145 jobs. A portion of the Bay Area's Computer & Electronic Product Manufacturing base is spreading to the Sacramento region, and employment in the sector expanded by 88.4 percent between 2010 and 2014. With a total of 4,341 jobs in 2014, Computer & Electronic Product Manufacturing is the largest manufacturing sector in the region.

Measured by 2014 employment, Fabricated Metal Product Manufacturing and Wood & Paper Products Manufacturing are the second and third largest manufacturing sectors in the region, with 3,052 and 2,131 jobs respectively.

In terms of number of establishments in 2014, Fabricated Metal Product Manufacturing leads the region with 208 establishments and Printing & Related Support Activities follows with 152 establishments.

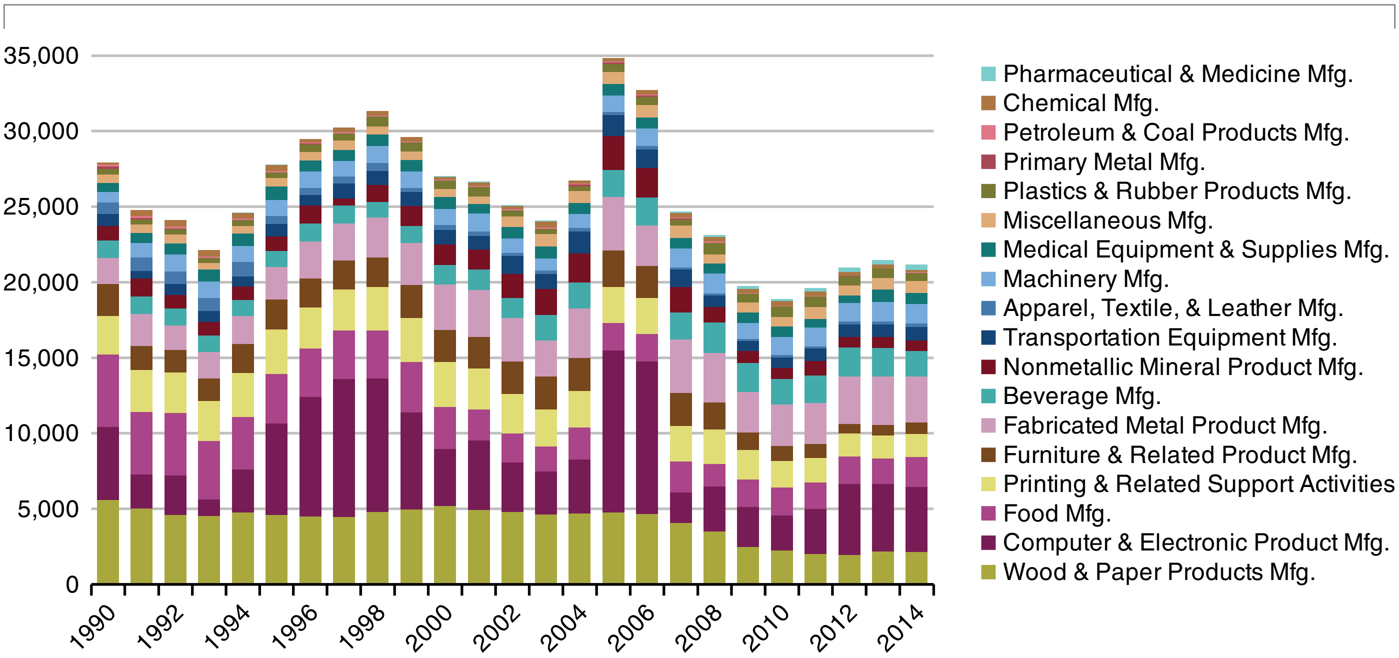
The strongest manufacturing employment growth in the Sacramento Area was in the Pharmaceutical & Medicine Manufacturing sector, which grew by 147.7 percent between 2010 and 2014.

Sacramento Area Manufacturing Employment Change by Sector, 2010–2014



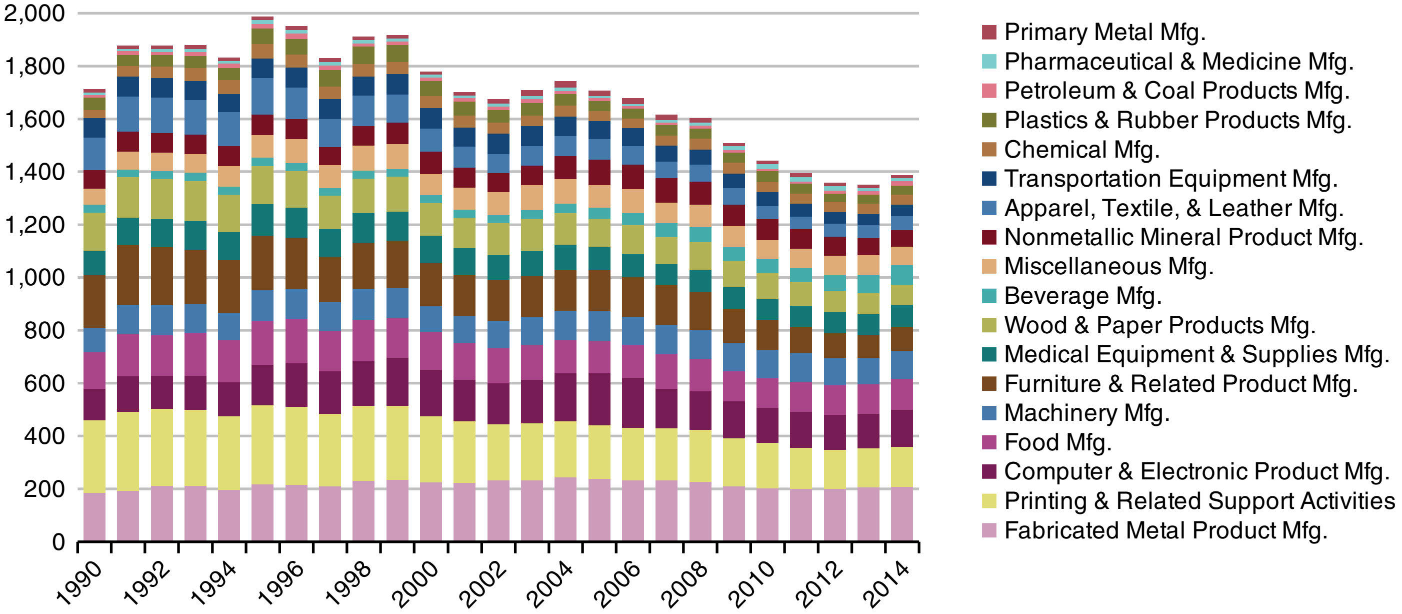
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Sacramento Area Manufacturing Employment by Sector, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Sacramento Area Manufacturing Establishments by Sector, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Northern California

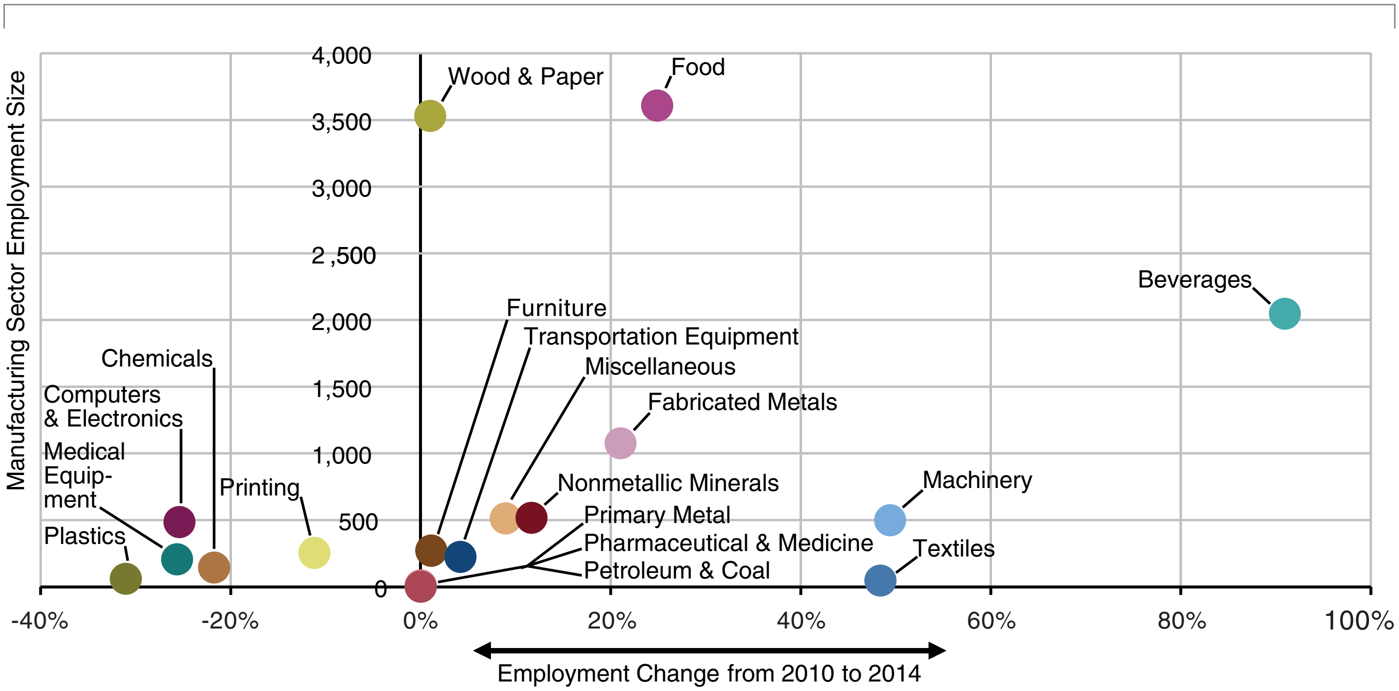
Northern California is defined as Butte, Colusa, Del Norte, Glenn, Humboldt, Lake, Lassen, Mendocino, Modoc, Plumas, Shasta, Siskiyou, Tehama, Trinity, and Yuba Counties. As of 2014, manufacturing accounted for 13,491 jobs in the region, or 4.0 percent of employment. Measured by 2014 employment, Food Manufacturing (with 3,608 jobs) and Wood & Paper Product Manufacturing (with 3,531 jobs) are the largest Northern California manufacturing sectors, each making up over 25 percent of manufacturing employment in the region.

Over the long term between 1990 and 2014, Food Manufacturing in Northern California experienced little or no change in employment and had a 4.2 percent decrease in number of establishments. However, in the 2010–2014 time period, Food Manufacturing in the region experienced growth on both fronts, with a 24.9 percent increase in employment and a 17.9 percent increase in establishments. In contrast, as the timber industry declined, Wood & Paper Product Manufacturing in the region saw decreases in both employment (-75.5 percent) and establishments (-50.6 percent over the 1990–2014 long term period and experienced only modest growth during the 2010–2014 recent period with a 1.0 percent increase in employment and a 1.1 percent increase in establishments.

Beverage Manufacturing is Northern California's fastest growing manufacturing sector, and experienced growth in both employment and establishments during the long-term period from 1990 to 2014. Driven by both vintners and brewers, employment in Beverage Manufacturing has experienced particularly strong recent growth, expanding by 91 percent between 2010 and 2014. During that same recent time period, the number of Beverage Manufacturing establishments expanded by 29 percent.

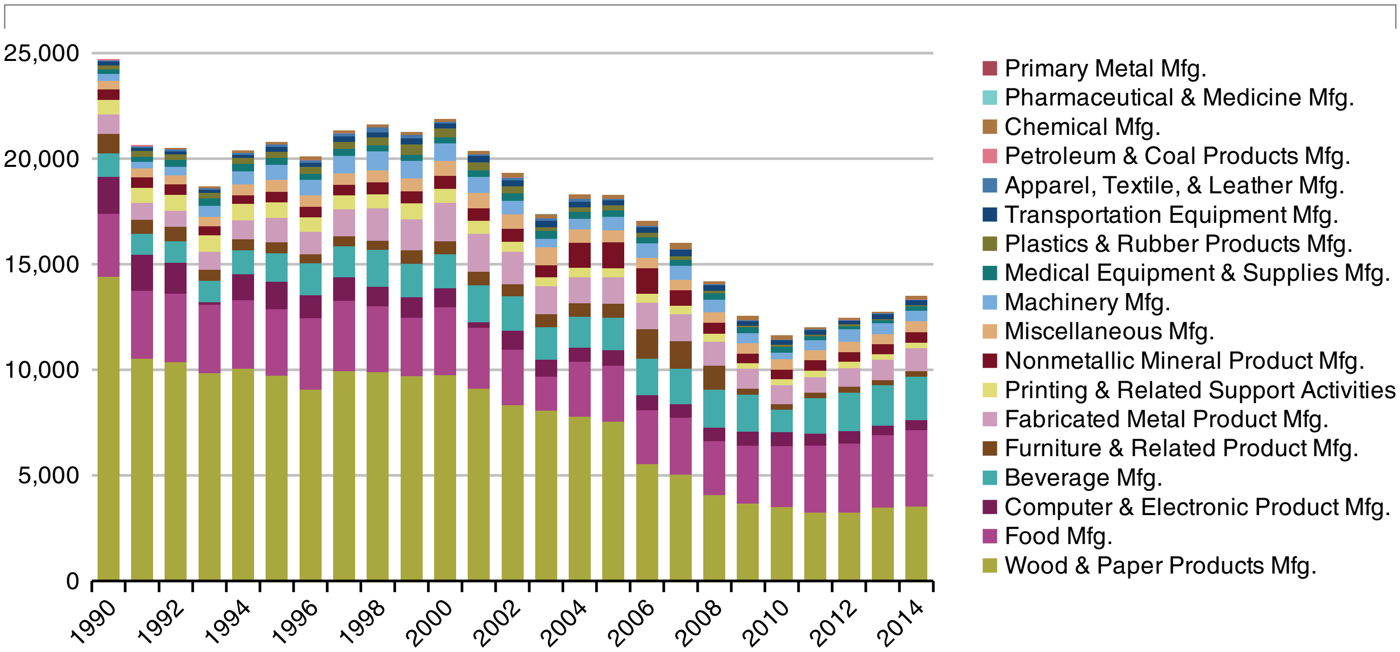
Machinery Manufacturing provided 499 jobs in Northern California in 2014 and expanded employment by 49.4 percent between 2010 and 2014, making it Northern California's second fastest growing manufacturing sector, measured by employment.

Northern California Manufacturing Employment Change by Sector, 2010–2014



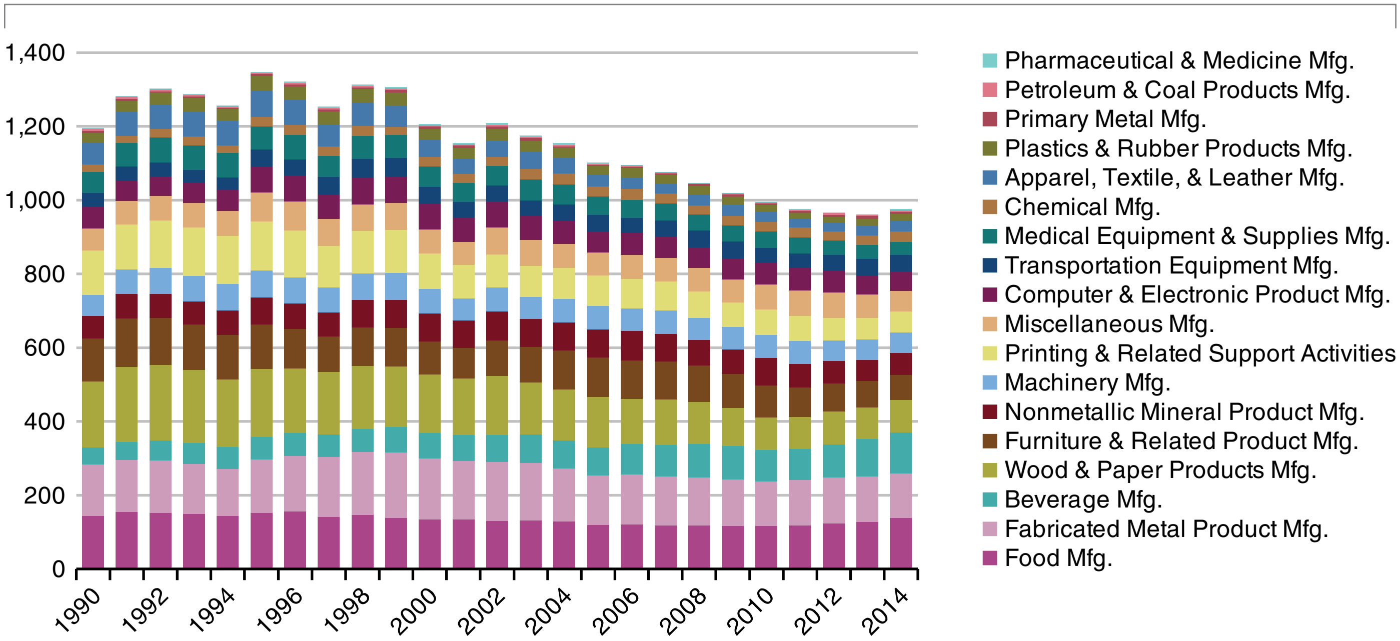
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Northern California Manufacturing Employment by Sector, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Northern California Manufacturing Establishments by Sector, 1990–2014



Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

APPENDIX A

Interviews

Mike Ammann – President, San Joaquin Partnership

Jose Anaya – Dean of Community Advancement, El Camino College

Geoff Annesley – General Manager of Manufacturing, E2open

Tom Baruch – Partner Emeritus / Strategic Advisor, Formation 8

Mark Benguerel – Chief Operating Officer, FineLite

Bob Burris – Senior Vice President, SACTO

Michael Cahill – President, Rail Systems Division, Siemens

Betsy Cantwell – Director for Economic Development, Lawrence Livermore National Laboratory

Brandon Cardwell – Executive Director, i-GATE iHub

Jacqueline Debets – Economic Development Coordinator, Humboldt County

Patrick Dempsey – Director of Strategic Engagements, Lawrence Livermore National Laboratory

David Dornfeld – Professor of Mechanical Engineering, UC-Berkeley

Mike Dozier – Office of Community & Economic Development, Fresno State University

Rob Eyler – Director of Center for Regional Economic Analysis, Sonoma State University

David Ginsberg – Vice President of Supply Chain Management, Sonic Manufacturing

Jesse Gipe – Manager, Economic Development, San Diego EDC

Ken Gracey – President, Parallax

David Flaks – President & Chief Operating Officer, LAEDC

Mark Hatch – CEO, TechShop

Rene van den Hoevel – Managing Director, German American Chamber of Commerce

Krisztina Holly – Entrepreneur-in-Residence, City of Los Angeles Mayor's Office

Dion Jackson – Associate, University of Southern California Center for Economic Development

Jimmy Jackson – Sr. Vice President of Public Policy, Biocom

Chris Johnson – Senior Director Government and Civic Engagement, Jabil

Mike Keer – Founder & CEO, Product Realization Group

Fariba Khoie – Bond Programs Manager, California Infrastructure and Economic Development Bank

Kelly Kline – Economic Development Director, City of Fremont

Kirk Klug – Director, Business Development, Siemens

Stewart Knox – Executive Director, Employment Training Panel

Ralf Kuschnereit – Head of Ophthalmic Systems Division, Carl Zeiss Meditec

John Lang – Chief Economist, City of San Jose

Tony Livoti – President, Monterey Bay International Trade Association

Gail Maderas – President & CEO, BayBio

Marc Madou – Chancellor's Professor, UC Irvine

David Mann – Director, Organization & Talent Development, Topcon Positioning Systems

Greg Matter – Executive Vice President, Jones Lang LaSalle

Leonard Mitchell – Executive Director, USC Center for Economic Development

David Moates – Consultant, California Manufacturing Technology Consulting

David Moore – Founder, Zero-Nine Design

Rich Moore – Engineering Manager, Scandic Springs

Jessica Pitt – Regional Workforce Coordinator, Design It – Build It – Ship It

Ramesh Ramamoorthy – Associate Laboratory Director, Lawrence Berkeley National Laboratory

Rich Robbins – President, Wareham Development

Hannalore Rodriguez-Farrar – Senior Advisor for Strategy and Planning, Dominican University

Dorothy Rothrock – President, California Manufacturers & Technology Association

William Ruh – Chief Digital Officer, General Electric

Gene Russell – President & CEO, The Corporation for Manufacturing Excellence - Manex

Kate Sofis – Executive Director, SFMade

Chris Stewart – Chairman & CEO, North Bay Life Science Alliance

Greg Theyel – Program Director, Biomedical Manufacturing Network

Audrey Taylor – President & CEO, Chabin Concepts

Rick Urban – COO/CFO, Quality Controlled Manufacturing, Inc.

Jim Watson – President & CEO, California Manufacturing Technology Consulting

APPENDIX B

Methodology

Data Source

Data on employment, establishments, and wages is from a custom tabulation of the Quarterly Census of Employment and Wages (QCEW) provided to the Institute by the California Employment Development Department, Labor Market Information Division. The Quarterly Census of Employment and Wages (QCEW) Program is a federal/state cooperative program between the US Department of Labor's Bureau of Labor Statistics (BLS) and the California EDD's Labor Market Information Division (LMID). The QCEW program produces a comprehensive tabulation of employment and wage information for workers covered by California Unemployment Insurance (UI) laws and federal workers covered by the Unemployment Compensation for Federal Employees (UCFE) program.

Employment and Wages

Employment data under the QCEW program represents the number of the state's UI covered workers who worked during, or received pay for, the pay period which includes the 12th of the month. Excluded are members of the armed forces, the self-employed, proprietors, domestic workers, and unpaid family workers. Railroad workers covered by the Railroad Unemployment Insurance system are also excluded. Wages represent total compensation paid during the calendar quarter, regardless of when services were performed. Included in wages is compensation for vacation and other paid leave, bonuses, stock options, tips, the cash value of meals, and lodging.

Workers on the payroll of more than one firm during the period are counted by each UI subject employer if they meet the employment definition noted above. Workers are counted even though, in the latter months of the year, their wages may not be subject to unemployment insurance tax. The employment count excludes workers who earned no wages during the entire applicable pay period because of work stoppages, temporary layoffs, illness, or unpaid vacations.

Establishments

An establishment is an economic unit, such as a farm, mine, factory, or store that produces goods or provides services. It is typically at a single physical location address and is engaged in one or predominantly one type of economic activity for which a single industry classification may be applied. Occasionally, a single physical location address encompasses two or more distinct and significant activities. Each activity should be reported as a separate establishment if separate records are kept and the various activities are classified under different NAICS codes.

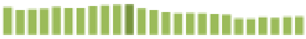
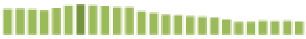
Patent Activity

Patent registration information covering location and investor sequence number was provided by the US Patent and Trademark Office. Patent counts refer to utility patents only.

APPENDIX C

California Manufacturing Regional Clusters Tables

Employment Change by Manufacturing Sector, Los Angeles Area 1990–2014

	Employment					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Beverage Mfg.	8,491	7,389	8,651	1.9%	17.1%	
Miscellaneous Mfg.	22,277	12,650	14,623	-34.4%	15.6%	
Fabricated Metal Product Mfg.	91,171	53,699	60,962	-33.1%	13.5%	
Furniture & Related Product Mfg.	44,431	17,889	19,676	-55.7%	10.0%	
Petroleum & Coal Products Mfg.	11,674	4,588	4,996	-57.2%	8.9%	
Nonmetallic Mineral Product Mfg.	25,152	11,049	11,970	-52.4%	8.3%	
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	24,649	16,023	17,038	-30.9%	6.3%	
Primary Metal Mfg.	22,780	10,995	11,530	-49.4%	4.9%	
Machinery Mfg.	43,471	23,069	24,100	-44.6%	4.5%	
Pharmaceutical & Medicine Mfg.	8,346	15,159	15,803	89.3%	4.2%	
Apparel, Textile, & Leather Mfg.	116,581	56,348	58,565	-49.8%	3.9%	
Transportation Equipment Mfg.	164,088	51,561	52,826	-67.8%	2.5%	
Plastics & Rubber Products Mfg.	37,205	22,458	22,725	-38.9%	1.2%	
Total Mfg. in the Region	**941,124**	**475,613**	**478,919**	**-49.1%**	**0.7%**	
Food Mfg.	62,641	46,986	46,836	-25.2%	-0.3%	
Wood & Paper Products Mfg.	35,634	17,160	16,602	-53.4%	-3.3%	
Printing & Related Support Activities	41,571	19,973	18,311	-56.0%	-8.3%	
Medical Equipment & Supplies Mfg.	15,153	14,724	12,819	-15.4%	-12.9%	
Computer & Electronic Product Mfg.	165,809	73,893	60,886	-63.3%	-17.6%	

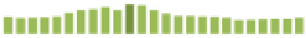
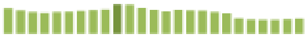
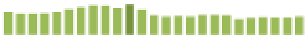
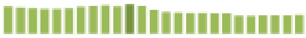
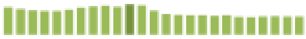
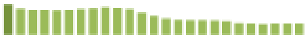
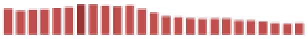
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Establishments Change by Manufacturing Sector, Los Angeles Area 1990–2014

	Establishments					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Beverage Mfg.	96	117	190	97.9%	62.4%	
Food Mfg.	1,349	1,305	1,353	0.3%	3.7%	
Computer & Electronic Product Mfg.	1,932	1,341	1,338	-30.7%	-0.2%	
Machinery Mfg.	1,594	1,119	1,111	-30.3%	-0.7%	
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	595	585	574	-3.5%	-1.9%	
Pharmaceutical & Medicine Mfg.	94	132	129	37.2%	-2.3%	
Miscellaneous Mfg.	985	938	908	-7.8%	-3.2%	
Medical Equipment & Supplies Mfg.	697	557	537	-23.0%	-3.6%	
Fabricated Metal Product Mfg.	3,716	2,801	2,688	-27.7%	-4.0%	
Plastics & Rubber Products Mfg.	871	629	598	-31.3%	-4.9%	
Petroleum & Coal Products Mfg.	88	80	76	-13.6%	-5.0%	
Total Mfg. in the Region	**23,698**	**17,665**	**16,650**	**-29.7%**	**-5.7%**	
Transportation Equipment Mfg.	1,108	815	757	-31.7%	-7.1%	
Wood & Paper Products Mfg.	758	600	553	-27.0%	-7.8%	
Printing & Related Support Activities	2,651	1,492	1,370	-48.3%	-8.2%	
Nonmetallic Mineral Product Mfg.	584	496	440	-24.7%	-11.3%	
Apparel, Textile, & Leather Mfg.	4,490	3,300	2,880	-35.9%	-12.7%	
Primary Metal Mfg.	400	336	287	-28.3%	-14.6%	
Furniture & Related Product Mfg.	1,690	1,022	861	-49.1%	-15.8%	

Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Employment Change by Manufacturing Sector, Bay Area 1990–2014

	Employment					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Transportation Equipment Mfg.	2,867	1,063	1,529	-46.7%	43.8%	
Nonmetallic Mineral Product Mfg.	9,653	4,438	5,825	-39.7%	31.3%	
Beverage Mfg.	11,829	17,774	20,793	75.8%	17.0%	
Machinery Mfg.	17,771	14,295	16,708	-6.0%	16.9%	
Food Mfg.	32,247	20,506	23,798	-26.2%	16.1%	
Furniture & Related Product Mfg.	7,272	3,932	4,254	-41.5%	8.2%	
Fabricated Metal Product Mfg.	25,458	18,896	20,347	-20.1%	7.7%	
Pharmaceutical & Medicine Mfg.	9,095	16,204	17,324	90.5%	6.9%	
Apparel, Textile, & Leather Mfg.	17,289	3,425	3,649	-78.9%	6.5%	
Total Mfg. in the Region	**426,428**	**280,399**	**293,847**	**-31.1%**	**4.8%**	
Computer & Electronic Product Mfg.	213,624	134,474	139,271	-34.8%	3.6%	
Medical Equipment & Supplies Mfg.	10,263	11,284	11,437	11.4%	1.4%	
Printing & Related Support Activities	20,458	7,464	7,531	-63.2%	0.9%	
Wood & Paper Products Mfg.	9,702	4,600	4,544	-53.2%	-1.2%	
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	11,858	4,040	3,828	-67.7%	-5.2%	
Primary Metal Mfg.	1,979	1,392	1,284	-35.1%	-7.8%	
Miscellaneous Mfg.	4,945	4,118	3,408	-31.1%	-17.2%	
Plastics & Rubber Products Mfg.	7,456	4,042	3,231	-56.7%	-20.1%	
Petroleum & Coal Products Mfg.	12,662	8,452	5,086	-59.8%	-39.8%	

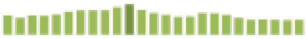
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Establishments Change by Manufacturing Sector, Bay Area 1990–2014

	Establishments					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Beverage Mfg.	329	690	890	170.5%	29.0%	
Food Mfg.	827	696	764	-7.6%	9.8%	
Machinery Mfg.	659	491	512	-22.3%	4.3%	
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	243	201	208	-14.4%	3.5%	
Computer & Electronic Product Mfg.	1,984	1,572	1,576	-20.6%	0.3%	
Wood & Paper Products Mfg.	354	228	227	-35.9%	-0.4%	
Total Mfg. in the Region	**11,229**	**8,309**	**8,257**	-26.5%	-0.6%	
Nonmetallic Mineral Product Mfg.	343	274	271	-21.0%	-1.1%	
Medical Equipment & Supplies Mfg.	484	415	410	-15.3%	-1.2%	
Transportation Equipment Mfg.	226	138	136	-39.8%	-1.4%	
Fabricated Metal Product Mfg.	1,632	1,279	1,226	-24.9%	-4.1%	
Miscellaneous Mfg.	450	377	340	-24.4%	-9.8%	
Pharmaceutical & Medicine Mfg.	61	129	116	90.2%	-10.1%	
Plastics & Rubber Products Mfg.	293	148	133	-54.6%	-10.1%	
Printing & Related Support Activities	1,550	738	645	-58.4%	-12.6%	
Apparel, Textile, & Leather Mfg.	950	379	329	-65.4%	-13.2%	
Furniture & Related Product Mfg.	665	417	361	-45.7%	-13.4%	
Petroleum & Coal Products Mfg.	70	52	44	-37.1%	-15.4%	
Primary Metal Mfg.	109	85	69	-36.7%	-18.8%	

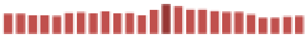
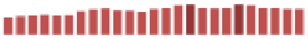
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Employment Change by Manufacturing Sector, Orange County 1990–2014

	Employment					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Medical Equipment & Supplies Mfg.	10,269	12,344	16,854	64.1%	36.5%	
Primary Metal Mfg.	1,016	401	495	-51.3%	23.4%	
Wood & Paper Products Mfg.	4,928	2,594	3,178	-35.5%	22.5%	
Food Mfg.	5,271	5,254	6,059	14.9%	15.3%	
Fabricated Metal Product Mfg.	23,870	20,064	22,976	-3.7%	14.5%	
Transportation Equipment Mfg.	27,036	8,144	9,072	-66.4%	11.4%	
Total Mfg. in the Region	**222,006**	**134,770**	**141,810**	**-36.1%**	**5.2%**	
Furniture & Related Product Mfg.	10,732	3,286	3,451	-67.8%	5.0%	
Machinery Mfg.	11,879	8,321	8,588	-27.7%	3.2%	
Miscellaneous Mfg.	4,879	3,984	4,073	-16.5%	2.2%	
Plastics & Rubber Products Mfg.	13,207	7,633	7,799	-40.9%	2.2%	
Apparel, Textile, & Leather Mfg.	9,640	7,436	7,506	-22.1%	0.9%	
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	3,422	2,656	2,636	-23.0%	-0.8%	
Beverage Mfg.	1,969	1,349	1,302	-33.9%	-3.5%	
Printing & Related Support Activities	12,210	8,299	8,000	-34.5%	-3.6%	
Computer & Electronic Product Mfg.	70,679	36,860	35,099	-50.3%	-4.8%	
Pharmaceutical & Medicine Mfg.	5,137	4,578	3,654	-28.9%	-20.2%	
Nonmetallic Mineral Product Mfg.	4,149	1,144	872	-79.0%	-23.8%	
Petroleum & Coal Products Mfg.	1,713	423	196	-88.6%	-53.7%	

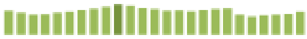
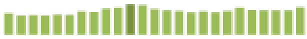
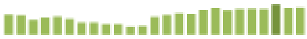
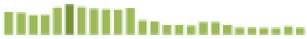
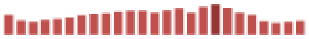
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Establishments Change by Manufacturing Sector, Orange County 1990–2014

	Establishments					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Beverage Mfg.	20	21	42	110.0%	100.0%	
Petroleum & Coal Products Mfg.	21	16	22	4.8%	37.5%	
Food Mfg.	252	250	277	9.9%	10.8%	
Medical Equipment & Supplies Mfg.	242	255	272	12.4%	6.7%	
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	145	164	168	15.9%	2.4%	
Computer & Electronic Product Mfg.	856	750	747	-12.7%	-0.4%	
Miscellaneous Mfg.	251	292	286	13.9%	-2.1%	
Fabricated Metal Product Mfg.	1,031	902	880	-14.6%	-2.4%	
Total Mfg. in the Region	**6,102**	**4,996**	**4,857**	**-20.4%**	**-2.8%**	
Machinery Mfg.	542	388	371	-31.5%	-4.4%	
Transportation Equipment Mfg.	306	248	236	-22.9%	-4.8%	
Plastics & Rubber Products Mfg.	282	195	184	-34.8%	-5.6%	
Printing & Related Support Activities	855	513	484	-43.4%	-5.7%	
Primary Metal Mfg.	51	49	46	-9.8%	-6.1%	
Wood & Paper Products Mfg.	200	163	151	-24.5%	-7.4%	
Nonmetallic Mineral Product Mfg.	152	101	93	-38.8%	-7.9%	
Pharmaceutical & Medicine Mfg.	37	63	56	51.4%	-11.1%	
Furniture & Related Product Mfg.	383	222	197	-48.6%	-11.3%	
Apparel, Textile, & Leather Mfg.	476	404	345	-27.5%	-14.6%	

Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Employment Change by Manufacturing Sector, Central Valley 1990–2014

	Employment					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Pharmaceutical & Medicine Mfg.	154	–	90	-41.6%	–	
Primary Metal Mfg.	637	270	516	-19.0%	91.1%	
Furniture & Related Product Mfg.	3,330	1,031	1,477	-55.6%	43.3%	
Printing & Related Support Activities	4,223	1,662	2,194	-48.0%	32.0%	
Apparel, Textile, & Leather Mfg.	1,878	296	390	-79.2%	31.8%	
Fabricated Metal Product Mfg.	8,872	6,679	8,526	-3.9%	27.7%	
Machinery Mfg.	6,232	4,960	6,318	1.4%	27.4%	
Beverage Mfg.	5,882	6,481	8,202	39.4%	26.6%	
Plastics & Rubber Products Mfg.	3,060	3,499	3,919	28.1%	12.0%	
Total Mfg. in the Region	**103,224**	**88,386**	**98,038**	**-5.0%**	**10.9%**	
Wood & Paper Products Mfg.	7,960	6,214	6,707	-15.7%	7.9%	
Nonmetallic Mineral Product Mfg.	6,758	4,337	4,665	-31.0%	7.6%	
Food Mfg.	43,589	44,248	47,260	8.4%	6.8%	
Petroleum & Coal Products Mfg.	683	1,041	1,106	61.9%	6.2%	
Miscellaneous Mfg.	1,310	726	770	-41.2%	6.1%	
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	1,138	1,481	1,545	35.8%	4.3%	
Computer & Electronic Product Mfg.	2,861	812	831	-71.0%	2.3%	
Medical Equipment & Supplies Mfg.	1,026	985	1,001	-2.4%	1.6%	
Transportation Equipment Mfg.	3,631	3,664	2,521	-30.6%	-31.2%	

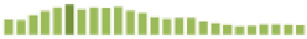
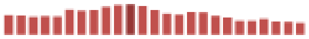
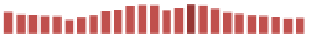
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Establishments Change by Manufacturing Sector, Central Valley 1990–2014

	Establishments					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Beverage Mfg.	90	146	201	123.3%	37.7%	
Plastics & Rubber Products Mfg.	93	97	108	16.1%	11.3%	
Miscellaneous Mfg.	97	101	107	10.3%	5.9%	
Apparel, Textile, & Leather Mfg.	138	71	75	-45.7%	5.6%	
Food Mfg.	481	542	571	18.7%	5.4%	
Machinery Mfg.	267	216	221	-17.2%	2.3%	
Computer & Electronic Product Mfg.	110	100	101	-8.2%	1.0%	
Total Mfg. in the Region	**2,978**	**2,734**	**2,743**	**-7.9%**	**0.3%**	
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	73	92	92	26.0%	0.0%	
Pharmaceutical & Medicine Mfg.	12	8	8	-33.3%	0.0%	
Printing & Related Support Activities	315	168	167	-47.0%	-0.6%	
Medical Equipment & Supplies Mfg.	117	90	88	-24.8%	-2.2%	
Petroleum & Coal Products Mfg.	30	43	42	40.0%	-2.3%	
Fabricated Metal Product Mfg.	402	442	425	5.7%	-3.8%	
Transportation Equipment Mfg.	111	110	105	-5.4%	-4.5%	
Wood & Paper Products Mfg.	191	174	154	-19.4%	-11.5%	
Nonmetallic Mineral Product Mfg.	140	136	116	-17.1%	-14.7%	
Primary Metal Mfg.	39	50	42	7.7%	-16.0%	
Furniture & Related Product Mfg.	272	148	120	-55.9%	-18.9%	

Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Employment Change by Manufacturing Sector, San Diego Area 1990–2014

	Employment					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Petroleum & Coal Products Mfg.	50	–	80	60.0%	–	
Beverage Mfg.	1,346	955	2,349	74.5%	146.0%	
Food Mfg.	3,637	2,899	4,744	30.4%	63.6%	
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	1,471	643	871	-40.8%	35.5%	
Primary Metal Mfg.	407	545	653	60.4%	19.8%	
Fabricated Metal Product Mfg.	5,648	5,335	6,184	9.5%	15.9%	
Pharmaceutical & Medicine Mfg.	1,924	5,110	5,903	206.8%	15.5%	
Apparel, Textile, & Leather Mfg.	3,256	1,856	2,040	-37.3%	9.9%	
Machinery Mfg.	3,801	6,446	7,064	85.8%	9.6%	
Furniture & Related Product Mfg.	4,759	1,623	1,745	-63.3%	7.5%	
Medical Equipment & Supplies Mfg.	5,918	5,855	6,241	5.5%	6.6%	
Total Mfg. in Region	**96,940**	**82,450**	**84,615**	**-12.7%**	**2.6%**	
Miscellaneous Mfg.	3,826	4,348	4,452	16.4%	2.4%	
Transportation Equipment Mfg.	18,913	13,166	13,152	-30.5%	-0.1%	
Printing & Related Support Activities	6,375	3,291	3,053	-52.1%	-7.2%	
Computer & Electronic Product Mfg.	30,211	25,432	22,134	-26.7%	-13.0%	
Wood & Paper Products Mfg.	1,260	882	756	-40.0%	-14.3%	
Nonmetallic Mineral Product Mfg.	1,922	1,652	1,413	-26.5%	-14.5%	
Plastics & Rubber Products Mfg.	2,216	2,412	1,781	-19.6%	-26.2%	

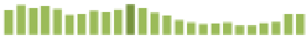
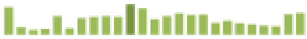
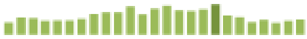
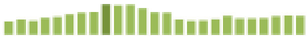
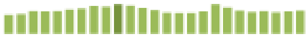
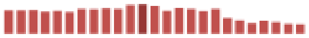
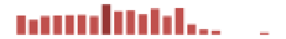
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Establishments Change by Manufacturing Sector, San Diego Area 1990–2014

	Establishments					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Beverage Mfg.	20	27	68	240.0%	151.9%	
Petroleum & Coal Products Mfg.	16	7	12	-25.0%	71.4%	
Food Mfg.	198	178	218	10.1%	22.5%	
Pharmaceutical & Medicine Mfg.	44	75	91	106.8%	21.3%	
Primary Metal Mfg.	29	28	33	13.8%	17.9%	
Machinery Mfg.	191	187	211	10.5%	12.8%	
Computer & Electronic Product Mfg.	488	481	503	3.1%	4.6%	
Total Mfg. in the Region	**3,458**	**3,046**	**3,096**	**-10.5%**	**1.6%**	
Fabricated Metal Product Mfg.	436	417	420	-3.7%	0.7%	
Miscellaneous Mfg.	215	249	247	14.9%	-0.8%	
Medical Equipment & Supplies Mfg.	162	165	163	0.6%	-1.2%	
Apparel, Textile, & Leather Mfg.	279	178	171	-38.7%	-3.9%	
Transportation Equipment Mfg.	165	169	162	-1.8%	-4.1%	
Printing & Related Support Activities	545	312	295	-45.9%	-5.4%	
Wood & Paper Products Mfg.	119	88	83	-30.3%	-5.7%	
Plastics & Rubber Products Mfg.	106	101	93	-12.3%	-7.9%	
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	63	78	70	11.1%	-10.3%	
Furniture & Related Product Mfg.	285	203	174	-38.9%	-14.3%	
Nonmetallic Mineral Product Mfg.	97	103	82	-15.5%	-20.4%	

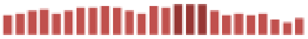
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Employment Change by Manufacturing Sector, Central Coast 1990–2014

	Employment					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	170	173	747	339.4%	331.8%	
Wood & Paper Products Mfg.	504	259	818	62.3%	215.8%	
Medical Equipment & Supplies Mfg.	798	203	573	-28.2%	182.3%	
Apparel, Textile, & Leather Mfg.	387	138	327	-15.5%	137.0%	
Transportation Equipment Mfg.	2,197	794	1,734	-21.1%	118.4%	
Beverage Mfg.	1,489	3,426	4,335	191.1%	26.5%	
Furniture & Related Product Mfg.	834	439	548	-34.3%	24.8%	
Machinery Mfg.	494	506	617	24.9%	21.9%	
TOTAL MFG. IN THE REGION	**29,285**	**19,709**	**23,460**	**-19.9%**	**19.0%**	
Miscellaneous Mfg.	843	1,036	1,223	45.1%	18.1%	
Printing & Related Support Activities	1,733	786	840	-51.5%	6.9%	
Fabricated Metal Product Mfg.	1,402	1,608	1,718	22.5%	6.8%	
Computer & Electronic Product Mfg.	7,474	5,081	5,352	-28.4%	5.3%	
Pharmaceutical & Medicine Mfg.	–	308	311	–	1.0%	
Petroleum & Coal Products Mfg.	190	244	234	23.2%	-4.1%	
Nonmetallic Mineral Product Mfg.	748	331	295	-60.6%	-10.9%	
Food Mfg.	9,732	4,005	3,566	-63.4%	-11.0%	
Plastics & Rubber Products Mfg.	290	372	222	-23.4%	-40.3%	
Primary Metal Mfg.	–	–	–	–	–	

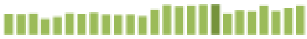
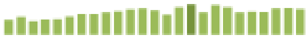
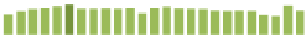
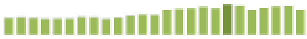
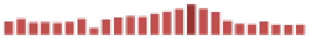
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Establishments Change by Manufacturing Sector, Central Coast 1990–2014

	Establishments					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Beverage Mfg.	64	218	297	364.1%	36.2%	
Petroleum & Coal Products Mfg.	6	11	13	116.7%	18.2%	
Machinery Mfg.	85	72	84	-1.2%	16.7%	
Wood & Paper Products Mfg.	50	47	53	6.0%	12.8%	
Food Mfg.	190	160	176	-7.4%	10.0%	
Computer & Electronic Product Mfg.	197	185	201	2.0%	8.6%	
TOTAL MFG. IN THE REGION	**1,562**	**1,428**	**1,538**	**-1.5%**	**7.7%**	
Miscellaneous Mfg.	80	82	86	7.5%	4.9%	
Medical Equipment & Supplies Mfg.	82	53	55	-32.9%	3.8%	
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	28	35	36	28.6%	2.9%	
Nonmetallic Mineral Product Mfg.	80	47	47	-41.3%	0.0%	
Printing & Related Support Activities	178	100	97	-45.5%	-3.0%	
Plastics & Rubber Products Mfg.	38	29	28	-26.3%	-3.4%	
Fabricated Metal Product Mfg.	170	179	172	1.2%	-3.9%	
Furniture & Related Product Mfg.	137	87	82	-40.1%	-5.7%	
Apparel, Textile, & Leather Mfg.	103	51	47	-54.4%	-7.8%	
Transportation Equipment Mfg.	56	45	41	-26.8%	-8.9%	
Pharmaceutical & Medicine Mfg.	5	14	12	140.0%	-14.3%	
Primary Metal Mfg.	13	13	11	-15.4%	-15.4%	

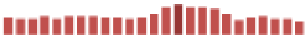
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Employment Change by Manufacturing Sector, Sacramento Area 1990–2014

	Employment					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Pharmaceutical & Medicine Mfg.	0	132	327	–	147.7%	
Computer & Electronic Product Mfg.	4,822	2,304	4,341	-10.0%	88.4%	
Petroleum & Coal Products Mfg.	134	43	64	-52.2%	48.8%	
Apparel, Textile, & Leather Mfg.	741	163	219	-70.4%	34.4%	
Transportation Equipment Mfg.	812	688	892	9.9%	29.7%	
Miscellaneous Mfg.	574	653	795	38.5%	21.7%	
TOTAL MFG. IN THE REGION	**27,911**	**18,887**	**21,145**	**-24.2%**	**12.0%**	
Fabricated Metal Product Mfg.	1,736	2,758	3,052	75.8%	10.7%	
Machinery Mfg.	712	1,192	1,318	85.1%	10.6%	
Food Mfg.	4,801	1,877	1,964	-59.1%	4.6%	
Medical Equipment & Supplies Mfg.	580	691	698	20.3%	1.0%	
Beverage Mfg.	1,130	1,668	1,678	48.5%	0.6%	
Wood & Paper Products Mfg.	5,593	2,257	2,131	-61.9%	-5.6%	
Nonmetallic Mineral Product Mfg.	961	749	706	-26.5%	-5.7%	
Printing & Related Support Activities	2,550	1,723	1,527	-40.1%	-11.4%	
Plastics & Rubber Products Mfg.	363	673	539	48.5%	-19.9%	
Furniture & Related Product Mfg.	2,127	1,000	759	-64.3%	-24.1%	
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	113	316	135	19.5%	-57.3%	
Primary Metal Mfg.	162	–	–	-100.0%	–	

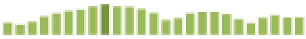
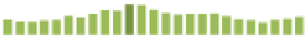
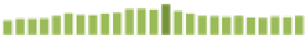
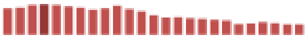
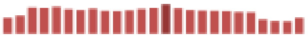
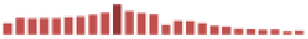
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Establishments Change by Manufacturing Sector, Sacramento Area 1990–2014

	Establishments					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Petroleum & Coal Products Mfg.	12	9	15	25.0%	66.7%	
Beverage Mfg.	30	52	74	146.7%	42.3%	
Apparel, Textile, & Leather Mfg.	124	49	53	-57.3%	8.2%	
Computer & Electronic Product Mfg.	120	131	139	15.8%	6.1%	
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	31	38	40	29.0%	5.3%	
Medical Equipment & Supplies Mfg.	91	80	84	-7.7%	5.0%	
Food Mfg.	137	114	118	-13.9%	3.5%	
Fabricated Metal Product Mfg.	185	203	208	12.4%	2.5%	
Machinery Mfg.	93	105	107	15.1%	1.9%	
Miscellaneous Mfg.	61	72	70	14.8%	-2.8%	
Total Mfg. in the Region	**1,713**	**1,442**	**1,386**	**-19.1%**	**-3.9%**	
Printing & Related Support Activities	275	172	152	-44.7%	-11.6%	
Transportation Equipment Mfg.	73	53	43	-41.1%	-18.9%	
Plastics & Rubber Products Mfg.	46	42	34	-26.1%	-19.0%	
Nonmetallic Mineral Product Mfg.	69	79	62	-10.1%	-21.5%	
Wood & Paper Products Mfg.	144	97	76	-47.2%	-21.6%	
Primary Metal Mfg.	13	13	10	-23.1%	-23.1%	
Furniture & Related Product Mfg.	201	116	89	-55.7%	-23.3%	
Pharmaceutical & Medicine Mfg.	8	17	12	50.0%	-29.4%	

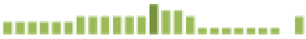
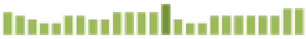
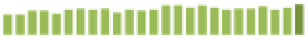
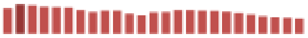
Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Employment Change by Manufacturing Sector, Northern California 1990–2014

	Employment					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Petroleum & Coal Products Mfg.	59	–	11	-81.4%	–	
Beverage Mfg.	1,099	1,072	2,047	86.3%	91.0%	
Machinery Mfg.	340	334	499	46.8%	49.4%	
Apparel, Textile, & Leather Mfg.	64	31	46	-28.1%	48.4%	
Food Mfg.	3,001	2,889	3,608	–	24.9%	
Fabricated Metal Product Mfg.	914	889	1,076	17.7%	21.0%	
TOTAL MFG. IN THE REGION	**24,728**	**11,611**	**13,491**	**-45.4%**	**16.2%**	
Nonmetallic Mineral Product Mfg.	518	463	517	-0.2%	11.7%	
Miscellaneous Mfg.	387	470	512	32.3%	8.9%	
Transportation Equipment Mfg.	181	215	224	23.8%	4.2%	
Furniture & Related Product Mfg.	926	268	271	-70.7%	1.1%	
Wood & Paper Products Mfg.	14,400	3,496	3,531	-75.5%	1.0%	
Printing & Related Support Activities	680	286	254	-62.6%	-11.2%	
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	–	184	144	–	-21.7%	
Computer & Electronic Product Mfg.	1,759	650	485	-72.4%	-25.4%	
Medical Equipment & Supplies Mfg.	208	277	206	-1.0%	-25.6%	
Plastics & Rubber Products Mfg.	192	87	60	-68.8%	-31.0%	
Pharmaceutical & Medicine Mfg.	–	–	–	–	–	
Primary Metal Mfg.	–	–	–	–	–	

Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Establishments Change by Manufacturing Sector, Northern California 1990–2014

	Establishments					
	1990	2010	2014	% Change 1990–2014	% Change 2010–2014	History 1990–2014
Pharmaceutical & Medicine Mfg.	2	1	3	50.0%	200.0%	
Petroleum & Coal Products Mfg.	5	2	4	-20.0%	100.0%	
Primary Metal Mfg.	6	5	7	16.7%	40.0%	
Beverage Mfg.	45	85	110	144.4%	29.4%	
Food Mfg.	144	117	138	-4.2%	17.9%	
Chemical Mfg. (excl. Pharmaceutical and Medicine Mfg.)	20	26	30	50.0%	15.4%	
Transportation Equipment Mfg.	39	41	45	15.4%	9.8%	
Apparel, Textile, & Leather Mfg.	60	28	29	-51.7%	3.6%	
Wood & Paper Products Mfg.	180	88	89	-50.6%	1.1%	
Fabricated Metal Product Mfg.	140	121	122	-12.9%	0.8%	
Total Mfg. in the Region	**1,195**	**995**	**976**	**-18.3%**	**-1.9%**	
Plastics & Rubber Products Mfg.	25	18	17	-32.0%	-5.6%	
Machinery Mfg.	58	63	57	-1.7%	-9.5%	
Computer & Electronic Product Mfg.	57	59	53	-7.0%	-10.2%	
Miscellaneous Mfg.	60	67	56	-6.7%	-16.4%	
Printing & Related Support Activities	120	69	56	-53.3%	-18.8%	
Nonmetallic Mineral Product Mfg.	60	74	58	-3.3%	-21.6%	
Furniture & Related Product Mfg.	117	87	68	-41.9%	-21.8%	
Medical Equipment & Supplies Mfg.	57	44	34	-40.4%	-22.7%	

Data Source: Quarterly Census of Employment & Wages, California EDD
Analysis: Bay Area Council Economic Institute

Notes

1. As of March 2015, employment in manufacturing sectors totaled 1,271,672 in California, representing 9.3 percent of the state's total employment. Texas followed with 887,901 production jobs, making up 9.1 percent. (US Bureau of Labor Statistics, Quarterly Census of Employment and Wages).

2. Ben-Shabat, Hana et al, "Connected Consumers Are Not Created Equal: A Global Perspective," A. T. Kearney, November 2014, <http://www.atkearney.com/consumer-products-retail/connected consumers>.

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4. A.T. Kearney's Reshoring Database is comprised of documented reshoring cases from different sources. For more on reshoring trends, see A.T. Kearney's white paper "Solving the Reshoring Dilemma" and "The Truth about Reshoring" full report.

5. The data is from "2010 World Robotics," a survey made by the International Federation of Robotics as reported by Jobin, Jean-Philippe, "Industrial Robots: 5 Most Popular Applications," *Robotiq Company Blog*, Feb. 2014, <http://blog.robotiq.com/bid/52886/Industrial-robots-5-most-popular-applications>.

6. Mims, C., "How Robots Are Eating the Last of America's—and the World's—traditional Manufacturing Jobs," *Quartz*, 15 Feb. 2013, <http://qz.com/53710/robots-are-eating-manufacturing-jobs/>.

7. Profactor, GmbH, "LOCOBOT Project Information," 2014, <http://www.profactor.at>.

8. Lean refers to the idea of maximizing customer value while minimizing waste or the resources required to deliver that value. Lean Enterprise Institute, "What is Lean?" <http://lean.org/whatsLean/>.

9. A.T. Kearney, "Silicon Valley Thought Leader Series, Internet of Things 2020: A Glimpse into the Future," <http://www.atkearney.com/web/internet-of-things-2020-a-glimpse-into-the-future/home>.

10. BI Intelligence, <https://intelligence.businessinsider.com>.

11. Nosbuch, Keith D. and John A. Bernaden, "The Multiplier Effect," *Manufacturing Executive Leadership Journal*, March 2012, <http://docplayer.net/241947-Multiplier-effect-manufacturing-executive-the-rockwell-automation.html>.

12. US Bureau of Labor Statistics, Quarterly Census of Employment and Wages. Texas followed California with 887,901 production jobs making up 9.1 percent.

13. CB Insights, "The New Manufacturing: Funding to Industrial IoT Startups Jumps 83% in 2015," March 3, 2016, <http://www.cbinsights.com/blog/industrial-iiot-funding>.

14. Manyika, James, et al., "Disruptive technologies: Advances that will transform life, business, and the global economy," McKinsey Global Institute, May 2013.

15. Li, Shan, "More U.S. companies opening high-tech factories in Mexico," *Los Angeles Times*, November 29, 2013, Online.

16. Bureau of Economic Analysis, "Finance and Insurance Led Growth in the Second Quarter," November 5, 2015, <http://www.bea.gov/newsreleases/industry/gdpindustry/2015/pdf/gdpind215.pdf>.

17. Bureau of Labor Statistics, "Industries at a Glance: Manufacturing: NAICS 31-33," <http://www.bls.gov/iag/tgs/iag31-33.htm>.

18. Scott, Elizabeth and Howard Wial, "Multiplying Jobs: How Manufacturing Contributes to Employment Growth in Chicago and the Nation," University of Illinois at Chicago, Center for Urban Economic Development, May 2013; Bivens, Josh, "Updated Employment Multipliers for the U.S. Economy," Economic Policy Institute, August 2003; DeVol, Ross C. et al., "Manufacturing 2.0: A More Prosperous California," Milken Institute, June 2009.

19. Bureau of Economic Analysis, "Industry-by-Industry Total Requirements Table," <http://www.manufacturing.gov/mfg_in_context.html>.

20. Levinson, Marc, "U.S. Manufacturing in International Perspective," Congressional Research Service, February 20, 2014.

21. Boroush, Mark, *NSF Releases New Statistics on Business Innovation*, National Science Foundation, Directorate for Social, Behavioral, and Economic Sciences InfoBrief NSF 11-300, October 2010.

22. Ibid.

23. US Census Bureau, US Bureau of Economic Analysis, "U.S. International Trade in Goods and Services, December 2014," February 5, 2015, <http://www.census.gov/foreign-trade/Press-Release/2014pr/12/ft900.pdf>.

24. Pisano, Gary P. and Willy C. Shih, "Restoring American Competitiveness," *Harvard Business Review*, July 2009.

25. Yamaner, Michael, "Federal Funding for Basic Research at Universities and Colleges Essentially Unchanged in FY 2012," National Science Foundation, National Center for Science and Engineering Statistics InfoBrief NSF 14-318, September 2014.

26. "Governor Cuomo Announces New York State to Build High-Tech Manufacturing Complex in Buffalo," Governor's Press Office, November 21, 2013. <https://www.governor.ny.gov/press/11212013-high-tech-manufacturing-complex-buffalo>.

27. Philips, Matthew, "Welders, America Needs You," *Bloomberg Businessweek*, March 20, 2014.

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