2011 Index of the Massachusetts Innovation Economy

MASSACHUSETTS TECHNOLOGY COLLABORATIVE
John Adams Innovation Institute

The Index of the Massachusetts Innovation Economy, published annually since 1997, is the premier fact-based benchmark for measuring the performance of the Massachusetts knowledge economy.

Massachusetts USA

Leading the Innovation Revolution

Dear Friends,

It is my pleasure to welcome you to the 2011 **Index** of the Massachusetts Innovation Economy. The **Index**, published annually by the Massachusetts Technology Collaborative (MTC), is the Commonwealth's instrument for assessing the performance of the state's innovation ecosystem and the key industry sectors of the innovation economy. The **Index** highlights key trends and themes affecting the state's Innovation Economy and helps inform fact-based decision-making among Massachusetts' policymakers, industry practitioners, and academic leaders.

Since 1997, the MTC has produced the **Index** report analyzing the innovation process, and capital and human resources that grow and sustain the Innovation Economy in the Commonwealth. This report, based on a set of 25 quantitative indicators, examines not only the strengths of the Massachusetts Innovation Economy, but also areas of concern that need to be addressed by the state if it is to remain at the forefront of innovation and economic development. The **Index** is a key tool for state leaders, public and private, to align our resources with the innovation process to meet emerging challenges and opportunities.

The Massachusetts Innovation Economy is one of the state's key advantages in the global economy and an engine of prosperity for our citizens. It is also a source of resilience amidst national and global economic uncertainty.

While the state continues to face challenges in these tough economic times, this edition of the **Index** shows that the Commonwealth, under the Patrick-Murray administration, has been able to maintain its leadership in the Innovation Economy. The Commonwealth retains its status as one of the most R&D intensive economies in the world. The Commonwealth is also among the leaders in attracting federal R&D dollars to its universities and nonprofit research institutes.

I invite you to read the **Index**, add your thoughts, and join our collaborative efforts to enhance Massachusetts as a leading center of the world's innovation revolution.

Gregory P. Bialecki, Secretary
Executive Office of Housing and Economic Development
Commonwealth of Massachusetts

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The Massachusetts Technology Collaborative

The Mass Tech Collaborative is the Commonwealth's economic development engine for facilitating and catalyzing innovation throughout Massachusetts.

The Mass Tech Collaborative bolsters innovation and job growth in the private sector for the good of the Commonwealth, providing a standard for government agencies by employing the collaborative model to create public benefit. It fosters collaborations among industry, government, and academia to sustain a thriving innovation economy in Massachusetts and strengthen the state's competitiveness globally.

The rich history of The Mass Tech Collaborative reaches back to 1982, when the Legislature created the Massachusetts Technology Park Corporation to develop a "partnership of government and industry and education" for the tech sector. As the state's economy evolved during the past thirty years, the Mass Tech Collaborative adapted and accommodated a changing marketplace by creating a foundation of collaboration, flexibility, and independence.

John Adams Innovation Institute

The John Adams Innovation Institute, an operating division of the Mass Technology Collaborative, is dedicated to fostering collaboration among business, government, universities, and other economic and civic institutions to improve the conditions for economic growth and job creation in the technology sector. Using industry clusters as an organizing concept, John Adams contributes its expertise, investment-making, problem-solving, and access to thought leaders and decision makers, to support innovation and technological changes in the marketplace. John Adams promotes innovation and economic growth through advancement of the following program objectives:

1. enhance and improve our collective understanding at the intersection of economic development and innovation
2. convene industry, government and academia as a primary means to enhance the economic competitiveness of recognized economic sectors
3. strengthen and support institutions focused on growing the innovation economy
4. support and sponsor civic entrepreneurs
5. intervene opportunistically in close collaboration with industry, academia and public sector stakeholders, especially in instances where, but for the intervention, a competitive advantage for the Massachusetts economy could be diminished.

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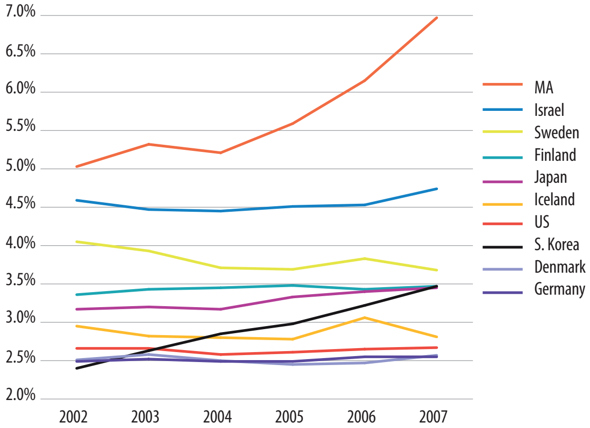
Highlights

The *Index*

Through 25 indicators, the **Index of the Massachusetts Innovation Economy** provides a comprehensive view of the performance of the Commonwealth's innovation ecosystem and its impact on the state's economic prosperity. Using a rich set of data sources, the **Index** benchmarks Massachusetts against nine Leading Technology States (LTS) to reveal relative strengths and weaknesses and compare the state's competitive position. Appendix A describes the LTS selection criteria. The nine LTS chosen for comparison in the **2011 Index** are California, Connecticut, Maryland, Minnesota, New Jersey, New York, North Carolina, Pennsylvania, and Virginia.

R&D performed as a percent of GDP, international and Massachusetts, 2002-2007



Source: United Nations Educational, Scientific and Cultural Organization (UNESCO) and the National Science Foundation

(Updated data for 2008 will be released by the National Science Foundation during the first quarter of 2012.)

Highlights

The share of Massachusetts' total employment concentrated in the eleven key sectors of the Innovation Economy increased to 38.4% in 2011.

Typically, these sectors provide some of the highest paying jobs in Massachusetts. Total wages paid in these key sectors were 23% higher in 2010 than in 2005, a larger increase than the 15% gain in the economy as a whole. The largest employer in these sectors in 2010 was Healthcare Delivery, with more than double the employees than the next closest sector, Financial Services. The Bio-pharma & Medical Devices sector saw the largest percent change in employment from 2006 to 2010 with a 27.0% increase.

Massachusetts is a national and global leader in research and development.

R&D represents a vital segment of the Massachusetts economy. As documented in previous editions of the Index, the Commonwealth has the most R&D intensive economy of the LTS and one of the most R&D intensive economies in the world. In Israel, for example—the leader among countries—R&D accounted for 4.7% of GDP in 2007, while R&D represented 2.7% of GDP in the United States as a whole. Massachusetts has also led the LTS in industry-performed R&D as a percent of private industry output.

Federal funding is a key enabler of research and development in Massachusetts.

Whether in total dollars or on a per capita basis, universities and nonprofit research institutes in Massachusetts were among the top in the LTS for attracting federal R&D dollars. Academic and nonprofit research institutes in the Commonwealth received $2.8 billion federal R&D dollars in 2008, accounting for 8.9% of the US total. At $435 per capita, federal expenditures for academic and nonprofit R&D were more than four times larger in Massachusetts than in the United States as a whole (per capita). The Commonwealth also maintained its leadership position among all LTS in funding from the National Institutes of Health (NIH) in 2010. Massachusetts's small businesses attracted 12.2% of all federal funding invested in 2010 through the Small Business Innovation Research (SBIR) Program, which funds proof-of-concept research and prototype development.

Massachusetts' universities and colleges are dynamic contributors to the state's Innovation Economy.

Universities and colleges attract and educate the highly-skilled and creative talent that gives the state a key competitive advantage in the global economy. Universities and colleges also contribute to employment, knowledge creation and dissemination, and new business formation. With approximately 140,200 employees (Q1 2011), the postsecondary education sector was the third largest employer among the 11 key sectors. Universities and colleges in Massachusetts performed nearly $2.17 billion dollars of R&D in 2007, or 43 % of all non-business R&D in the Commonwealth. In 2008 Massachusetts led the LTS in the amount of industry funding of academic research per capita, with a narrow lead over North Carolina. In 2009, universities in Massachusetts reached a 14-year high in licensing and options revenue, bringing in $162 million. While university spin-outs account for only a small fraction of overall new business formation, Massachusetts' universities perform exceptionally well in this measure. Forty-nine businesses spun out from universities in Massachusetts in 2009, second only to California with 84. Per capita, Massachusetts maintains a substantial lead.

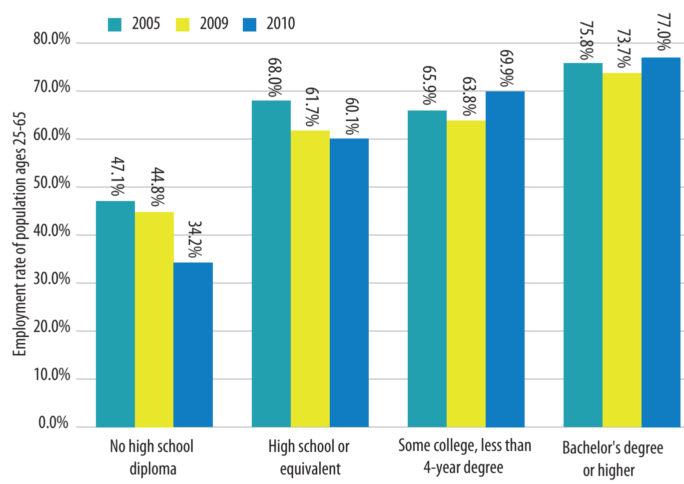
Entrepreneurship has remained vibrant and well supported in Massachusetts even amidst economic uncertainty and a slowdown in business establishment openings.

In 2010, the number of business establishments opening in Massachusetts fell to its lowest level since 1995, reflecting the slow economic recovery from the recent recession. Four of the LTS, including Massachusetts, had fewer business establishments opening in 2010 than 2009. Yet, entrepreneurial activity, estimated by the Kaufman Foundation as the percentage of businesses started by people who did not previously own a business, increased in Massachusetts and nationwide. This estimate increased nationally from 0.28% of the population during 1998-2000 to 0.33% during 2008-2010, while it increased in Massachusetts from 0.16% to 0.29% during the same time periods. New businesses in Massachusetts were also being relatively well funded. In 2009 and 2010, venture capital going to startup, seed, and early stage businesses in Massachusetts reached its highest level since the height of the 2000 tech bubble, with $1.7 billion invested.

Jobs created in the Massachusetts economy increasingly require advanced degrees.

Compared to the 2006 average, the Massachusetts economy as a whole showed a net loss of 88,600 jobs in the first quarter of 2011. In the same period employment in the key sectors of the Innovation Economy had a net increase of 24,100 people. Employment gains specific to these sectors suggest that jobs are being created in industries that normally require associate's degrees or other higher. Not surprisingly, full-time employment rates in Massachusetts show that more highly educated individuals are more likely to be employed. Between 2005 and 2010, the full-time employment rate of the working-age population in Massachusetts hovered at around 76% for individuals with a bachelor's degree or higher. At the other end of the spectrum, the full-time employment rate for individuals without high school shows a downward trend over the same period.

Full-time employment rate by education, Massachusetts, 2005, 2009, 2010

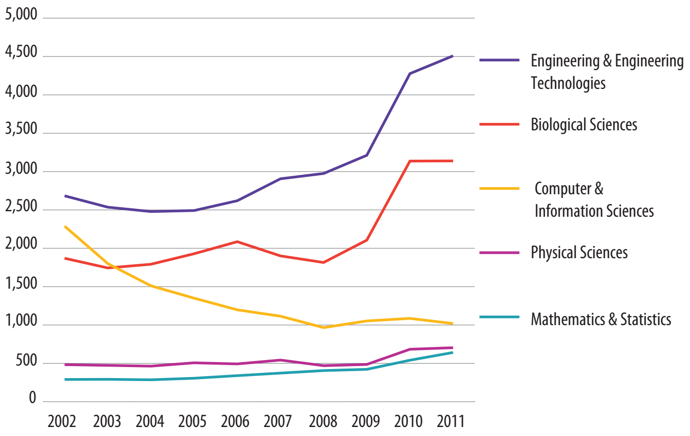


Source of all data for this indicator: US Census Bureau, Current Population Survey

Massachusetts' appropriations for public higher education continue to decline, whether viewed per student, per capita, or relative to the size of the economy.

Massachusetts' appropriations per student in public higher education are now 6.9% below the US average, compared to 2003 when they were 23% above. From 2009 to 2010 appropriations fell 2.2% while enrollment rose 6.3%, resulting in a 8.0% decline in appropriations per student. Among the fifty states, the size of this gain is in the middle of the pack being 28th overall.

Intended major of high school seniors, Massachusetts, 2002-2011



Source: The College Board

Interest in Science, Technology, Engineering, and Math (STEM) fields is increasing among Massachusetts' high school students, but the state is still 8.7% below the national average.

In science and mathematics, Massachusetts' high school students outperform their US peers and are highly competitive internationally. Their interest in STEM careers had remained notoriously low when compared to the LTS, but a comparison between 2006 and 2011 shows the gap between ability and interest has narrowed. While in 2006 the percent of high school students intending to major in STEM fields was lowest in Massachusetts among the LTS, by 2011 the state had moved up the rankings to sixth out of ten. Also in 2011, the percentage of Massachusetts' high school students intending to major in STEM fields reached the highest level since record keeping began eleven years ago. This increase was driven largely by interest in engineering & engineering technology majors and biological sciences majors. Interest in computer and information sciences declined steadily between 2003 and 2008, but has started to rebound since 2008.

Introduction

MASSACHUSETTS IS ONE OF THE WORLD'S LEADING innovation economies, and one of its most distinctive characteristics is its ability to continuously reinvent itself. Throughout its history, the state has excelled—and often has led the nation and the world—in pushing the frontiers of science and creating new domains of research and technology. The innovation that takes place here has fueled the rise of new industries such as digital technology, biotechnology and medical devices and transformed established industries with new processes, practices, and tools, like the machinery of mass production and the analytical instruments serving today's research enterprises.

The self-renewal capacity of our economy rests upon individual creativity and is amplified by a rich innovation ecosystem. Thousands of entrepreneurial and creative people choose Massachusetts to learn, innovate, work, and live, and they benefit enormously from our vibrant environment of universities, laboratories, companies, hospitals, private and public investment, and diverse business services.

Since its first release 15 years ago, in 1997, the Index of the Massachusetts Innovation Economy has examined and benchmarked the state of our innovation ecosystem. With the guidance of the Index Advisory Committee, the Index has established a national and global standard for quality and objectivity among the universe of publications that seek to measure regional innovation-based economic trends. In Massachusetts, the Index helps inform evidence-based decision-making in industry, academia and government. As a data-driven communications tool, it signals the importance of innovation in our economy and triggers attention, conversations, and media references.

The Index focuses on data that highlights what merits the attention of policy, academic, business and civic leaders in the state, including both emerging strengths and opportunities and worrisome trends and current challenges. We update indicators every year in response to the evolution of our economy and new or more precise knowledge about the innovation process. We bring additional or more accurate data sources to bear, and add or subtract measures and whole indicators. Our Advisory Committee strives to preserve independence and long-term thinking, seeking to inform policy priorities without inferring conclusions or making recommendations that follow what is fashionable in policy and management circles. The Index highlights the multiple dimensions of the ecosystem, but refrains from suggesting simplistic causal relationships and recommendations for complex problems. We offer interpretations but leave the conclusions to an informed audience.

This year the Index once again documents the commanding position of the Massachusetts Innovation Economy nationally and worldwide. Massachusetts continues to be a global leader in research and innovation. Eighty measures within the 25 indicators examine and benchmark our innovation economy along multiple dimensions in five categories: research, technology and business development, capital, and talent. We hold leadership positions—sometimes globally—in many measures. Relative to the size of our economy we attract a disproportionate amount of federal research dollars. We publish more academic publications per capita than anywhere else in the world. In our most prized natural resource, our people, Massachusetts excels by having the most educated workforce in the country and we continue to attract highly educated individuals. By other measures the picture is not as good. While we rank first in our amount of Small Business Innovation Research (SBIR) dollars per capita, attracting nearly three times more than our next closest competitor, our share of national SBIR awards has declined since 2000, though this decline appears to have stabilized. Similarly, we lead in venture capital (VC) investment per capita, but our share of national VC investment is declining as other states catch up. We also face the ever-present challenge of finding ways for the un- and underemployed and less-educated to acquire the skills necessary to work in our innovation economy industries.

While quantitative assessments are at the core of the Index, we recognize that not all truths can be measured. That is why the Index incorporates a special analysis section whenever pertinent. Many emerging trends, opportunities and concerns in our innovation economy escape easy categorization and require special attention. They are hard to quantify and only become evident through in-depth exposure to our regions and our research, innovation, and industry communities and are captured best through a combination of anecdotes, stories, and empirical evidence.

In this year's special analysis section, we examine a phenomenon, interdisciplinary innovation, made possible by a distinctive feature of the Massachusetts Innovation Economy: its diversity.

Unlike other regions and emerging innovation ecosystems elsewhere, which may have one or two successful industries, Massachusetts' universities, companies, and entrepreneurs excel in numerous fields, from design and architecture to biopharmaceuticals, robotics, and social media. They embody a staggering array of research, innovation, and entrepreneurship capabilities that have been developed and leveraged since the Industrial Revolution—and at an accelerated pace since World War II. In recessions, this diverse portfolio of industries and capabilities dampens the effects of downturns in our economy. In times of major industrial restructuring or decline, capabilities are redistributed and recombined in surprising ways, fueling the rise of novel business segments and sometimes of whole new industries that lay new foundations for prosperity.

In good and bad times, conversations that cross the boundaries of the diverse fields and industries in our economy lead to the discovery and pursuit of some of the most exciting and promising innovation and business opportunities. For decades, these interactions at the intersection of disciplines, industries, business segments and technology domains have been a key driver of technological, business and industrial change in our economy. The medical devices industry, for example, emerged at the intersection of medicine and analytical instrumentation. And yet what happens at the intersections of innovation is often poorly understood.

In the pages that follow five individuals share with us concrete examples of innovation and business opportunities at the intersections of innovation in Massachusetts. Ted Acworth shares with us an inspiring example of what happens when advanced technology intersects with design and the arts to reinvent an ancient art and build a successful business. Richard Himmelwright discusses the potential of digital printing to revolutionize the textile and apparel industries and James Watkins discusses roll-to-roll technology as an emerging example of technology borne out of nanomanufacturing research. Both of these technologies use cutting-edge research and new technology in revolutionary applications to enhance the competitiveness of old process-based industries. Building on her experience at MIT, Liz Reynolds describes how universities perform interdisciplinary research to respond to the world's most pressing challenges while reflecting on ways to facilitate this type of research. Richard Watson reflects on how design can play a key role in helping businesses better link technology, markets, and users and reminds us that understanding people and culture is often as important as technical expertise in order to innovate successfully.

Together, these five voices reflect on the organizational, talent and funding challenges of research and innovation at the intersections and on the possibilities to accelerate and amplify what happens there. They remind us that connecting the dots in our diversified and ever-changing portfolio of research, innovation, and business capabilities in Massachusetts offers numerous opportunities for innovation. Just look at what already is emerging. Systems biology and bioinformatics thrive where biology and computing blend. Mobile computing is transforming a vast swath of life and business, from marketing and entertainment to medicine. Advanced materials and digital technologies are driving incremental and radical innovation in energy generation, storage, and transmission. Design is transforming how we think and organize for innovation in industries like financial services and healthcare. They also remind us of the enormous potential for innovation by integrating new knowledge and technology into established processes and business segments that sustain and create jobs right now in existing industries. From construction and manufacturing to textiles, innovation in what exists already is as important as developing completely new products and industries. Himmelwright writes succinctly: "Everything we do does not have to be brand new."

Building collaboration and promoting the emergence of new relationships and communities that cross the boundaries of disciplines and industries is a powerful catalyst of discovery and innovation. How do we do this? One way is through the provision, maintenance, creation, and management of opportunities and spaces for dialogue and exploration among specialists and experts from different fields and industries.

We find explicit or implicit references to this idea in the commentaries. Liz Reynolds introduces the concept of "public space" to highlight its significance.[1] We find these spaces in our universities, in research centers such as James Watkins' Center for Hierarchical Manufacturing at UMass Amherst and Liz Reynolds' Industrial Performance Center at MIT. There, interdisciplinary teams engage in research that combines multiple science and engineering disciplines with an understanding of business, society, and politics to examine big issues like energy innovation, climate change, and nanoscale science and engineering. We find these public spaces throughout regions and industries in the state, in regular meetings such as Mobile Mondays and Mass Innovation Nights. We find these spaces in the hallways, kitchens, and seminar rooms of the Cambridge Innovation Center, where entrepreneurs bump into each other and talk. We find them in conferences, such as MassTLC's Unconference, TedX Boston, and IdeaMill in Holyoke. We find them in entities like the Robotics Cluster and the Design Industry Group of Massachusetts that Ted Acworth mentions. All of these are public spaces where meetings, dialogue, and exploration help combine knowledge, generate new ideas, build interdisciplinary communities, and launch projects. They are precursors of innovative action.

As the Index enters its 15th year, business, policy, and academic leaders in Massachusetts are more aware than ever before about the importance of research, innovation, and entrepreneurship capabilities as foundations of our economy. Similarly, our understanding of the innovation process and its impact on the economy continues to increase. In the upcoming year, the Index Advisory Committee will lead an effort to envision and implement ways to make the Index more useful, more relevant and more inspiring. We need, for example, to gain a deeper understanding of emergent phenomena that escape easy quantification, such as how our diversified technological and industrial capabilities recombine and lead to novelty at the intersections of innovation.

Complex sociotechnical phenomena like innovation require multiple lenses to be understood comprehensively. Inevitably, many aspects cannot be measured easily or at all. That is the case of what happens at the intersections of innovation, but we can still take action to seize the new opportunities we see and sense. To do so, we must use every tool at our disposal and sometimes we need to invent new ones. We need to embrace novel ways to promote innovation and industry clusters—such as through the preservation, creation, and management of public space. And in our economic development policy and practice, we need our industry executives, academic leaders, and government policymakers to balance coordinated activity with decentralized creativity; a focus on existing markets with new and unexpected ones; and an emphasis on urgent current needs with longer-term concerns. It is in the crevices and intersections of our innovation ecosystem, and the countless conversations at the margins, where the future of our economy is emerging. Freedom of exploration, ambiguity, variety, serendipity and surprise: These are the sources of innovation.

1 The concept of public space was introduced a few years ago at the MIT Industrial Performance Center as a conceptual device to apprehend a "missing dimension" of the innovation process. See Lester, Richard K. and Michael J. Piore, Innovation: The Missing Dimension. Harvard University Press, (2004). See also Breznitz, Dan "Collaborative public space in a national innovation system: a case study of the Israeli military's impact on the software industry," in Industry and Innovation Vol. 12 No.1 (2005).

Island of Misfit Toys

Edward "Ted" Acworth, Ph.D., Founder and CEO, ARTAIC – Innovative Mosaic

Before becoming a full-time entrepreneur I spent most of my life in academia in New York City, Palo Alto and the two Cambridges (Massachusetts and England). Everywhere, promising research was happening at the intersections of disciplines. Think about robotics, which can combine mechanical engineering, electronics, control systems, software, vision and artificial intelligence. I have always been excited by bridging "stove-piped" disciplines. Throughout my life this inclination has led me to look for opportunities where few people have. Interdisciplinary niches are novel and exciting, full of opportunities to create breakthrough products, often less competitive, tap (and create) big markets, and make unexpected contributions to society.

Artaic was born out of a search for opportunities between disciplines. Founded in 2007 as an MIT spinout, we are now an early growth stage company based in Boston's Innovation District. Artaic aims to revolutionize the ancient mosaic art form through "mass customization." Just as custom print technology transformed the carpet industry 30 years ago and spawned a multibillion-dollar industry, Artaic aims to transform the $76 billion global tile industry. We create beautiful custom tile mosaics using our proprietary technologies that combine robotics, advanced manufacturing, and computer aided design systems, and our access to artists and design professionals. Our customers now include Sheraton, Hyatt, and Tropicana, and locally our mosaics are on display at Salem Five Bank, MIT, Legal Sea Foods, G2O Spa, the Cambridge Innovation Center, Boston Children's Hospital and many other commercial and residential locations. Last year we piloted a residential e-commerce sales channel with the first-ever customizable product at The Home Depot.

Given what Artaic is, what disciplines and skills we draw upon and what markets we tap into, Massachusetts is arguably the best place on Earth to start and grow our business. We operate at the intersection of some of the world's most powerful innovation clusters. We manufacture our product in Boston for customers locally, in the US, and abroad, benefiting from the state's rich and diverse history in manufacturing and its concentration of advanced manufacturing capabilities. It's little known today that Massachusetts is where the American industrial revolution began in the 19th century, and that today 8,000 Massachusetts manufacturing companies make it the 4th largest sector in the State. Massachusetts manufacturing is a $40B growth industry. Our process is automated with robotics, and we benefit from our $1B robotics cluster—one of the strongest in the world—growing at 17% per year. And we also benefit from Massachusetts' world-class cluster of excellence in design. We have a large concentration of architecture firms and around 45,000 architects, graphic designers, product designers, and other creative professionals.

Like any start-up here, Artaic benefits by being part of Greater Boston's innovation ecosystem. We have cutting-edge research, education, and many entrepreneurial support resources such as venture capital. And yet, it was not easy to fund the launch of Artaic. We defy categorization. Our business does not fit into the standard pattern recognition of venture capital. We do not fall into any of the usual venture capital focus areas such as IT, biotech or medical devices. Venture capitalists invest where their funding model makes sense, and it was hard to make sense of our market and business model. Moreover, manufacturing and robotics are perceived as capital-intensive and not explosive-growth, venture-grade investments. "Maker" companies have a hard time raising capital. But Artaic has found funding from a variety of sources: founder investment, sweat equity, friends and family, loans, grants from the National Science Foundation, prize money from MassChallenge, barter. And best of all: Revenue.

Our most valuable asset is people. A benefit of Artaic's uniqueness has been that finding qualified employees has not been a challenge. Massachusetts and Boston concentrate some of the most talented scientists, engineers, designers, artists, and business professionals in the world. We look for people with a mix of technical, art, business and making—polymaths and life-long learners used to change, with multiple experiences and careers, and respectful of other disciplines and approaches. STEM is not enough for us. One of our employees double-majored in art and math. Another started school in engineering and then switched to graphic design while continuing to take courses in economics, engineering, and advertising. Yet one more started in architecture, moved to sculpture and materials, and after school acquired management experience as a professional set builder. For our production group we have partnered with Artisan's Asylum to hire artists and makers.

Massachusetts has plenty of resources available to help young businesses get off the ground. I have been pleasantly surprised at the number of public initiatives and quasi-public agencies. But there is little public awareness about what is available. When I was looking to locate the Artaic facility I searched for months until I stumbled across the artist loft space newsletter. From there I stumbled onto Create Boston, and that led to the City of Boston helping us locate at 21 Drydock Avenue and a Boston Redevelopment Authority loan. I wish there had been a single place or web resource to point me in the right direction quickly. Making the array of currently available resources more findable to entrepreneurs would make a real difference, as would connecting and mutually reinforcing these resources.

Massachusetts also has myriad opportunities to connect through initiatives such as Design Museum Boston, the Design Industry Group of Massachusetts (DIGMA), MassChallenge, the Robotics Cluster organized by the Mass. Technology Leadership Council, and more recently the Advanced Manufacturing Collaborative. In addition to bringing visibility to our many innovation communities, they create spaces to build relationships, identify common issues, connect with other entrepreneurs and with educational institutions, discover business opportunities, and launch collaborative projects. Importantly, these spaces help connect across industries and disciplines, and foster ideas and successful high-growth businesses at the intersections of innovation, like Artaic.

Artaic is somewhat of a misfit, as are most businesses at the intersections of innovation. These businesses are crucial to build the future of our economy, but it takes time for others and for markets to make sense of them. Our funding community and policymakers would do a great service to entrepreneurs and businesses like mine, if they remained attentive to emerging innovation and business opportunities outside of traditional focus areas. In Artaic we embrace diversity, embrace the misfits, and encourage multidisciplinarity. Maybe Massachusetts is, and should be, like an Island of Misfit Toys—a sanctuary where winged lions fly, cowboys ride ostriches, and robots make art. Imagine the possibilities.

Ted Acworth, Ph.D., founded Artaic LLC in 2007—a groundbreaking provider of "mass customized" artistic mosaics for the $76B global tile market. Artaic's innovative design software and robotic manufacturing systems enable the creation of unique tile solutions with short lead times and exceptional value.

Manufacturing Innovation

Richard S. Himmelwright, Ph.D., Cold Spring Technology, Inc. & 27 Gaylord LLC

Over the last year, I have been encouraged by how business, academic, and policy leaders are recognizing that Massachusetts and the United States cannot maintain our leading position in the global economy without a solid manufacturing base. Innovation is essential to maintain our strength in manufacturing and regain what we have lost.

I have been fortunate to grow up in Massachusetts. Here, I had the privilege of working in Edwin Land's Polaroid when it was still a major force in our state. At Polaroid I learned that innovative manufacturing is as important as new product development. Polaroid was a vivid example of how innovation in manufacturing was the engine for a large part of the success of Massachusetts' industries. But we have missed some key opportunities to bring innovation to existing industries. To be sure, we constantly need to push the limits of science and technology and develop totally new products and processes, but we can have a tremendous impact on existing industries by infusing innovation to established processes and businesses.

My personal focus and source of pride and accomplishment has come from the commercialization of technology in very large and small companies. I worked in the chemicals and coatings industry for almost thirty years, and I have devoted much of my career to bring new technology to process-based manufacturing businesses. While leading research and development at a large paper and film coating company based in Western Massachusetts, we brought substantial innovations to the imaging, medical, electronics and other industry segments while dramatically reducing the impact on the environment. The introduction of water-based and 100% solids radiation-cured processes advanced manufacturing capabilities and also reduced the environmental impact substantially. Like this experience, there are numerous examples of new technology enabling existing businesses and improving manufacturing processes. However, it seems this often does not receive the focus needed to allow the significant progress to be realized.

One example that we have worked on over the past several years is directed at bringing innovation to the Massachusetts textile industry. At the start of this project I was surprised to learn that there was still a Massachusetts textile printing industry in existence. Well, there is. A driven group of people is working hard to maintain a competitive position in a difficult worldwide marketplace.

The textile printing industry is a process-based manufacturing industry with well-established processes in place. The need for a competitive advantage to help maintain and grow business volume is at a critical point. The Massachusetts Office of Technology Assistance, working with MTC's John Adams Innovation Institute, has put energy and resources into understanding this industry segment and identifying areas of potential investment. My company has worked on this project now for a few years, and we started with a simple question: Can high-speed digital ink jet printing impact the textile printing industry? We discovered that the answer is yes. After working through a detailed collaborative process, we found that this technology can make a huge difference in the textile printing process. Implementing high-speed digital ink jet printing in the textile and apparel industry will allow economic and profitable short runs, near-zero inventory, very rapid new product development cycles and an improved competitive position for the industry.

The key step in the project required a team of individuals with broad experience in many technologies. The use of digital ink jet printing has transformed many printing industry segments. However, even though ink jet printing has become one of the most advanced industry processes currently being utilized in many varied production environments, bringing digital ink jet printing to high speed textile printing required one key innovative step. Recognizing that there was a stabilized web carried in the existing rotary screen press was the single major breakthrough in the project. This understanding allowed the team to realize that a printing unit could be constructed and retrofitted onto existing, expensive hardware, thereby enhancing the capabilities of textile printing companies.

The project will also bring radiation curing capability to the high-speed textile printing machines. This cure technology is advancing at a very rapid rate. The benefits include reduced solvent use, dramatically reduced energy use and improved product quality. In the most advanced state of this technology the use of blue-light cured inks, being developed at UMass Dartmouth, could potentially reduce energy demands further and eliminate the dangers of UV radiation from the process.

The hurdle for acceptance of new technology and taking the risk involved with being the first to adopt new technology is always high, particularly in an economic downturn. Training manufacturing technicians to run and maintain somewhat more sophisticated equipment is also challenging. However, the basic elements of a manufacturing process require focus on product quality, efficiencies and high yield. These characteristics are generally part of a company's manufacturing culture if the company has existed for any length of time. Providing adequate training and hands-on run experience will be a critical element in achieving ultimate success from this project.

Massachusetts is fortunate to have a stronger economy than many other states as we navigate a difficult economic environment. Massachusetts is also fortunate in that there are many opportunities to expand the type of collaborations required to generate true competitive advantage for our process industries. Our project was possible thanks to a strong collaboration between government, academia and industry that we would like to build on in the future. The potential is enormous, and I believe it can make a difference for manufacturing in Massachusetts. There are many examples of very large investments in specific technology segments such as biotech and energy production; which are indeed necessary for our country to move forward. However, in many instances these huge investments have yielded very little in overall economic or job growth. Further, the focus on large "home run" investments, I believe, has driven funding away from more modest investment opportunities that could enhance, grow and sustain existing manufacturing sectors.

Bringing innovation to established industries is as important as establishing new industry segments for Massachusetts' continued economic strength. And there is a very satisfying feeling of accomplishment associated with seeing products that are already utilized by people and businesses in various applications being manufactured more efficiently, safely and in an environmentally friendly manner. This example shows that the development of all new technology is critical to our success, but not the only thing we need to drive forward. Enhancing established processes with new technology and with alternative processing steps is vital to the prolonged success of manufacturing in our state and our economy as a whole. Everything we do does not have to be brand new.

Richard Himmelwright, Ph.D., a Massachusetts native, is the founder of Cold Spring Technology, Inc., a company that develops materials and coatings for a variety of applications. He also co-founded a new venture, 27 Gaylord LLC, that is focused on developing manufacturing technology for innovative new products.

Intersections that Matter

Elisabeth Reynolds, Ph.D., Executive Director, MIT Industrial Performance Center

Today we take for granted the idea that innovation is enhanced by a diverse range of perspectives and multidisciplinary teamwork. This was not always the case. In the 1940s, MIT built Building 20, a warehouse of sorts for the growing Radiation Laboratories that were acting as the Defense Department's research center during World War II. After the war, Building 20 became the destination for a hodgepodge of departments and campus activities that needed space: electronics, nuclear science, linguistics, acoustics. There was no rhyme or reason to which researchers or departments were located in the building, and therein lay the beauty of it. The juxtaposition of various departments and teams of researchers crammed together produced an enormously creative and innovative environment that led to many postwar scientific breakthroughs.

Seventy years later, research teams, departments and buildings, whether in a university or company setting, are expressly created with this interaction of diverse perspectives in mind. The Broad Institute, created in 2004, focuses on issues related to the biological sciences bringing together researchers from a wide variety of fields, and in addition, from two separate institutions, Harvard and MIT. The recently-opened Koch Institute for Integrative Cancer Research also is designed for maximum interaction between diverse teams of researchers that cross the boundaries of engineering, medicine and the life sciences to focus on curing one of society's deadliest diseases.

As has been suggested elsewhere, the most interesting questions and challenges that exist today are at the intersections of disciplines. Whether it is curing cancer, developing renewable energies or building airplanes, the complexity of the challenge has increased as has the knowledge required to tackle it. As the level of specialization needed to understand a particular issue has deepened, research in teams rather than by individuals has become the norm, teams that often represent diverse backgrounds and training. It also turns out that some of the best research (as measured by citations) is conducted by teams that work near each other, i.e., collaboration within close proximity produces some of the best work. This last point seems out of step with a world in which global connectivity is increasingly enhanced and communication across distances practically frictionless. Yet, the value of face-to-face interactions and collaborations persist.

If interdisciplinary teams working in close proximity are a critical component to the innovation process, how can we best promote this? One important element is the creation of "public spaces" that allow for the kinds of discussions that lead to innovative breakthroughs. Based on work conducted at MIT's Industrial Performance Center (IPC), Faculty Co-Chairs Richard Lester and Michael Piore describe the innovation process as comprised of two dimensions[1]—analysis, which focuses on specific problem solving, and interpretation, an open-ended process that allows for exploration and ambiguity around a common area of interest. While many teams and organizations can excel at the analytic process, the interpretive process is more challenging to develop and sustain. Creating "public spaces" where teams can engage in the interpretive process, whether within a company, a university or a regional "community of practice", is a critical part of building an environment that supports interdisciplinary, innovative work.

1 *Innovation: The Missing Dimension*, Harvard University Press, 2004.

Two current projects at the IPC highlight the value of this kind of space, both addressing complex issues facing the country today. MIT's Production in the Innovation Economy project is an institute-wide Commission begun in 2011 to look at the relationship between innovation and production, and whether there are ways the U.S. can gain more of the downstream benefits from its innovative capacity. The research team draws from several departments in engineering (aerospace, electrical, mechanical, nuclear) as well as political science, economics, and management. This allows for inquiry not only into new technologies and how they are changing manufacturing processes across industries, but also the economics of manufacturing, the management of supply chains and global operations, and the role public policy plays in affecting firm decisions about production. Without this multi-faceted approach to the topic, there would be an incomplete picture of the importance of manufacturing to the U.S. economy.

Likewise, the IPC's Energy Innovation Project necessarily takes an interdisciplinary approach to the challenge of clean energy and energy independence in the U.S. The project assesses the strengths and weaknesses of the US energy technology innovation system, considering the complexity of government incentives, regulations, markets, and public and private institutions. Again, understanding the energy industry and how to build a system less dependent on fossil fuels cannot be understood or addressed from just one discipline or perspective.

We have many examples in Massachusetts where this kind of interdisciplinary approach and "public space" exists—within innovative companies, universities, and within and across industry clusters. Creating the space for these conversations requires incentives to bring individuals to the table. In universities, interdisciplinary research often does not reward academics as much as individual work, while companies can be concerned about protecting intellectual property. Financial resources can support and encourage these conversations, for example, with funding for collaborative research centers and projects and shared infrastructure.

All of this requires a culture conducive to the open, interactive, cross-cutting conversations required to spark ideas and sustain collaboration at the intersections of innovation. This point might be the most challenging to address because culture is not easily fixed with money—though that helps—or public policy. But the building blocks for the culture we'd like to foster are already here. They are in the networks of people who share common and complementary interests, a high level of mutual trust, and that engage in collaborative, often risky, activities. Nurturing these "trust networks" takes time but the rewards can be significant, and the process itself an exciting one.

Elisabeth Reynolds, Ph.D. is the Executive Director of the MIT Industrial Performance Center (IPC), a multi-disciplinary research center dedicated to the study of innovation, productivity and competitiveness in the U.S. and around the world.

Roll-to-Roll Innovation

James J. Watkins, Ph.D., Director, NSF Center for Hierarchical Manufacturing, University of Massachusetts – Amherst

Massachusetts has been the home of many manufacturing innovations over the years in which basic materials are transformed into sheets, rolls, spools, reams and even featherweight wisps of technically sophisticated products. The textile industry gave Massachusetts its legendary fabric mills. Our paper industry, with nearly three dozen mills in the Bay State today and dozens more paper-converting and nonwovens companies has historically been innovative at transforming ordinary materials into high-value sheet products. These papermaking origins, often in combination with chemical and material technologies, have given rise to successful technology-based Massachusetts businesses in diverse fields such as instant photographic film, separation membranes, filtration media, advance printing and holographic coatings, polymer anti-shatter films for car windshields, and flexible solar panels.

We are now at a new intersection of technologies that can potentially spur innovation and economic growth. Thanks to a global trend toward mass production of flexible electronic displays, solar cells and many other thin-film materials and devices, manufacturers are looking for innovative continuous-feed processes for printing devices on flexible substrates. To meet industry needs and consumer demand, roll-to-roll technology is moving in the direction of extreme miniaturization of critical feature sizes to the nanoscale. Many of the new techniques of roll-to-roll nanomanufacturing involve using chemical and materials technology to print devices with features smaller than 1/1000 of the width of a human hair on thin, flexible film on a moving web.

Seen by industry as a game-changer for progress in printed electronics, this intersection of two technologies—volume production on continuous rolls of film, and nanofabrication technology—brings many opportunities to the fore. The diverse product applications of roll-to-roll range high on the value chain and match well with Massachusetts' advanced manufacturing companies and our state's skilled work force. They include not only electronic and energy devices such as solar cells, sensors, antennas, memory, displays, capacitors and batteries, but also many other functional materials such as barrier layers, security films, transparent conductor layers, magnetic metamaterials, chem/bio shielding, water-repellent surfaces, filtration/separation membranes and other products incorporating nanomaterials-on-film.

Roll-to-roll nanomanufacturing comes with many benefits. These include low unit costs, high-volume rates of production, efficiency through sequential application of successive layers on a web, energy and materials efficiency, versatility in the types of devices that can be made, form-factor benefits of flexibility and low weight, and relatively benign and plentiful constituent chemicals and materials.

During the past twenty years, many in the nanotechnology research community have strived to achieve production-ready solutions from the promise of materials and device technology at the nanoscale. At the University of Massachusetts Amherst's Center for Hierarchical Manufacturing, supported by the National Science Foundation, we are creating roll-to-roll nanomanufacturing advances that open the door to true high-volume printed nanoscale device production on a moving web. Our scientists tackle industry-relevant problems such as continuous nanoscale patterning at the device level, achieving nanometer-scale smoothness in the device layers, and printing or coating of hybrid polymer-nanoparticle materials for desired device performance. In contrast to the deposit-and-etch-away approach typical of silicon wafer fabs, we focus on the chemical and material interactions between components, creating active nanohybrid layers in which the system spontaneously assembles itself into predictable and adjustable nanoscale structures as the coating process proceeds. This research effort originating in UMass Amherst's Polymer Science and Engineering Department is one of the few in the world where nanoscale fabrication techniques meet roll-to-roll platform technology. In partnership with Massachusetts companies, this national center has designed and built several roll-to-roll pilot tools to demonstrate how the advances produced by the CHM can be scaled to viable manufacturing platforms.

Research and development in the US of roll-to-roll nanomanufacturing is modest compared to more vigorous technology development in Asian and European research centers and companies. Significantly more emphasis has been placed on nanomanufacturing of devices using a semiconductor production paradigm. However, when costs of up to $25,000 per square meter for fab-built chips are compared with target costs of $25 per square meter for roll-to-roll device processing, it is logical that over time more products will gravitate to the low-cost process.

Massachusetts is in the right place at the right time for this technology. For American competitiveness in printed electronics and nanotechnology-enabled products, the development of industrial ecosystems at the regional level can be an effective strategy. Roll-to-roll technology and tools are in many ways high-tech extensions of techniques that are already used in the advanced coatings, printing and flexible electronics industries. It is possible for Massachusetts companies that are engaged in these sectors to readily climb the product and device value chain, creating jobs and opportunity. R&D partnerships with institutions such as UMass Amherst, MIT and others working in this area can catalyze further advances.

The Patrick Administration has been strongly supportive of innovation in advanced manufacturing. It is my hope that Massachusetts' industry innovators will converge around opportunities such as printed electronics and roll-to-roll processing for the economic betterment of our state. Academic research centers like ours are ready to work with industry to translate laboratory proof-of-concept to scaled high-rate integrated processes, and thus contribute to Massachusetts' innovation ecosystem for advanced manufacturing.

James J. Watkins, Ph.D. is Professor of Polymer Science and Engineering at the University of Massachusetts Amherst and Director of the NSF Center for Hierarchical Manufacturing.

Integration through Design

Richard Watson, Partner and Co-Founder, Essential

Massachusetts has innovation in its DNA. Our history is tied to a culture of innovation that has transformed over time adapting to changing economic environments, creating some of the most disruptive technologies, products and systems in the world. As our innovation culture evolves, our rich science and technology clusters, higher education system, financial sector and creative economy continue to inspire entrepreneurs to grow a myriad of new businesses.

Massachusetts consistently targets its innovation culture to unexpected areas when others have not even seen the opportunity. Today a revolution is unfolding enabled by the ability to connect quickly and simply with our social networks through technology. This revolution of social interconnectedness is combining new strengths of Massachusetts' innovation (such as cloud computing, digital gaming, social networking, and mobile communications), with established industries in which the state has a longstanding reputation. Unexpected combinations are expanding the ways we think about healthcare, mobility, education, energy management and the way we live in our homes, creating new user experiences and business models along the way. Cloud-based social interconnectedness is opening a whole new set of user-driven innovation and business opportunities.

To capture these opportunities requires entrepreneurs to "connect the dots" between diverse emerging technologies and cultural trends to create new business models that are increasingly defined by an enhanced human connection. Our innovation and design consultancy, Essential, operates in this space. We partner with entrepreneurs and business leaders to help them connect ideas with business needs, understand what is possible with technology, and how it all relates to users. We are part of a local community of design and innovation consultancies that includes IDEO, Continuum, Mad Pow—among several others—who are creating exciting new product and service solutions. With roots in interdisciplinary design, Essential started 10 years ago, and has evolved from a product development focus to a wider set of capabilities that help create human-centered solutions and experiences across many industries and contexts. We bring together a multidisciplinary community of researchers, industrial designers, interface designers, mechanical engineers, and others. An interdisciplinary culture and approach helps us reveal hidden market opportunities and deliver compelling solutions that bring together technology, business and the human experience.

One of our past clients MeYou Health, a local healthcare start-up that was founded to engage, educate and empower people to pursue healthy lifestyles. MeYou Health is successfully combining social gaming, which builds on Massachusetts' long history in game development, with new applications that change how we think about and manage our health. The same game mechanics, now evolved beyond an entertainment focus, are being deployed in social networks to create products that promote sustained healthy change and well-being and engage with people across a vast range of interests and needs. For example "The Daily Challenge" utilizes email and apps to connect people with achievable daily tasks. The social value of the design is a feeling of more control and convenience over maintaining a positive sense of wellbeing. By empowering individuals to make small-but-positive steps on a daily basis, it is helping individuals and their social networks achieve better and longer-term well-being outcomes.

MeYou Health is not alone. Several other local innovators such as Healthrageous and Patients Like Me are all creating compelling connected health solutions driven by the ability to not only analyze data, but to dissect it, visualize it, and present it in a way that enables compelling new patient experiences. Connected health platforms are now a central component in the portfolio of most major healthcare providers. These technologies are not only transforming healthcare delivery, but are also being applied to workflow productivity, disease management and patient compliance. They will play a major role in reshaping our healthcare system.

The same social interconnectedness that is driving connected health is fueling innovation elsewhere. One example is the contagious explosion in traditional sharing, bartering, lending, renting, and swapping, now reinvented through online social networks. An early success story was Zipcar, now global but founded and based in Cambridge. Based on old European car sharing models, ZipCar focused on students and young professionals who didn't own a car but needed one occasionally for errands and short trips. In 1999 connecting the dots in this way was visionary. Now companies such as Relay Rides, which focuses on neighbor-to-neighbor car sharing, and the Hubway bicycle sharing initiative, are further reinforcing the momentum behind this movement. And this model is rapidly spreading to other activities. TaskRabbit allows you to connect with people who can help fulfill basic tasks such as picking up the groceries and house cleaning. ThredUP allows you to buy, sell, trade or share kids clothing, toys and books. These are just the tip of the iceberg in a new interconnected and more social approach to online commerce that is riding what has been described as major behavioral shifts among a new generation who doesn't necessarily value ownership in the same way as past generations. Why own a car? It can be such a burden.

Discovering opportunities and making connections at the intersections of innovation between technologies and users requires bringing together science and engineering expertise coupled with a deep understanding of people and culture. With so many science and technology based industries in Massachusetts, the cluster of excellent design professionals that are also here creates a tremendous opportunity for the Massachusetts economy. From the tech sector, to life sciences to clean energy to manufacturing, the design community is a massive resource.

I am encouraged by the efforts of Massachusetts' colleges and universities that are bringing together engineers, designers, and artists in projects that intersect technology and society. Such learning experiences help our future professionals, employees and leaders to develop the integrative capacity to connect across disciplines, appreciate different ways of thinking, and reinforce the collaborative spirit necessary for human-centered innovation. Beyond our schools, we need more spaces and more opportunities to build connections between the design community and industry. With our strengths in design, science, and technology, Massachusetts has a unique opportunity to lead the new wave of technological, human-centered, and connected innovation.

As a founding partner at Essential, a design and innovation in company in Boston, Richard Watson is a leading advisor to companies on product innovation and an authority in the field of design strategy. He is also an accomplished designer of award-winning products and services.

Massachusetts Innovation Ecosystem

Taken together, the 25 indicators in the **Index** examine the performance of the Commonwealth's innovation ecosystem through several lenses. To help organize and navigate these indicators, the **Index** classifies them in three categories: economic impact, innovation activities, and innovation capacity. The sequencing and logic of indicators suggest how performance in one arena may affect performance in others, as well as overall results.

Economic Impact

A key goal of the **Index** is to convey how innovation impacts the state's economy. One way innovation contributes to economic prosperity in Massachusetts is through employment and wages in the key industry clusters [Indicator #1]. Jobs created in the innovation economy are often high paying [Indicator #2], which directly and indirectly sustains a high standard of living throughout the Commonwealth [Indicator #3]. This capacity hinges on the ability of individual firms to utilize innovative technologies and processes that improve productivity [Indicator #4] and support the creation and commercialization of innovative products and services. Industry output is a measure of economic activity [Indicator #5]. An export-orientation is becoming an increasingly important driver of business and overall economic growth [Indicator #6]. Success in the national and global marketplaces brings in the revenue that enables businesses to survive, prosper, and create and sustain high-paying jobs.

Innovation Activities

In the **Index**, innovation is defined as the capacity to continuously translate ideas into novel products, processes and services that create, improve, or expand business opportunities. The **Index** assesses innovation by examining three categories of activities that underlie this complex and interactive process.

Research

The massive and diversified research enterprise concentrated in Massachusetts' universities, teaching hospitals, and government and industry laboratories [Indicators #7 and #8] is a major source of the new ideas that fuel the innovation process. Research activity occurs within a spectrum that ranges from curiosity-driven fundamental science, whose application often becomes evident once the research has started, to application-inspired research which starts with better defined problems or commercial goals in mind. Academic publications [Indicator #9] and patenting activity [Indicators #10 and #11] reflect both the intensity of new knowledge creation and the capacity of the Massachusetts economy to make these ideas available for dissemination and commercialization.

Technology Development

In close interaction with research activities, but with a clearer application as a goal, product development begins with research outcomes and translates them into models, prototypes, tests, and artifacts that help evaluate and refine the plausibility, feasibility, performance, and market potential of a research outcome. One way in which universities, hospitals, and other research institutions make new ideas available for product development by businesses and entrepreneurs is through technology licensing [Indicator #12]. Small Business Innovation Research (SBIR) grants enable small companies to test, evaluate, and refine new technologies and products [Indicator #13]. In the medical device and biopharma industries, both significant contributors to the Massachusetts Innovation Economy, regulatory approval of new products is an important milestone in the product development process [Indicator #14].

Massachusetts Innovation Ecosystem

Business Development

Business development involves commercialization, new business formation [Indicator #15], and business expansion. For existing businesses, growing to scale and sustainability often involves an initial public offering (IPOs), a merger or an acquisition (M&A) [Indicator #16]. Technical, business, and financial expertise all play a role in the process of analyzing and realizing business opportunities, which result after research and development are translated into processes, products, or services. Business model innovation also creates value but is not measured by the Index due to difficult quantification.

Innovation Capacity

The performance of the Massachusetts innovation ecosystem is greatly enhanced by a number of factors that increase the capacity for innovation by scientists, engineers, entrepreneurs, and firms in the Commonwealth.

Capital

Massachusetts attracts billions of dollars of funding every year for research, development, new business formation, and business expansion. The ability to attract public funds sustains the unparalleled capacity of individuals and organizations in the state to engage in the most cutting-edge and forward-looking research and development efforts [Indicator #17]. Universities in Massachusetts benefit from industry's desire to remain at the cutting edge of research and product development through university-industry interactions [Indicator #18]. For new business formation and expansion, Massachusetts' concentration of venture capitalists and angel investors is critical [Indicator #19]. Investors in these areas, capable of assessing both the risk and opportunities associated of new technologies and entrepreneurial ventures, are partners in the innovation process and vital to its success.

Talent

Innovation may be about technology and business outcomes, but it is a social process. As such, innovation is driven by the individuals who are actively involved in science, technology, design, and business development. The concentration of men and women with postsecondary and graduate education [Indicator #20], complemented by the strength of the education system [Indicator #21] provides the Commonwealth with competitive advantages in the global economy. Investment in public education helps sustain quality and enhance opportunities for individuals of diverse backgrounds to pursue a high school or college degree [Indicator #22]. Students and individuals with an interest or background in science, technology, engineering, and math [Indicator #23] are particularly important. Massachusetts also benefits from an ongoing movement of people across its boundaries, including some of the brightest people from the nation and world who chose to live, study, and work in the Commonwealth [Indicator #24]. Housing affordability influences Massachusetts' ability to attract and retain talented individuals [Indicator #25].

Massachusetts Innovation Ecosystem *continued*

There are a number of aspects of a region's capacity for innovation that are important, but are not directly measured in the **Index**:

Institutional Framework

The work of innovators in Massachusetts occurs within, and is supported by, an outstanding constellation of organizations that are critical for the innovation process. These include research universities, mission-oriented national laboratories, corporate laboratories, and research-based commercial ventures. Civic organizations, trade groups, and funding organizations operating across industries and regions are also an important part of the institutional framework for innovation. Finally, service providers such as patent lawyers, management consultants, and scientific and technical consultants make vital contributions throughout the innovation process.

Connections, Interactions, and Mobility

Ongoing interaction among the people involved in research, development, and entrepreneurship sustains the flow of new ideas and the discovery of opportunities that fuel the innovation process. These interactions include formal and informal conversations, joint projects, student internships, and many other relationships that span organizational—and often geographic—boundaries. The mobility and communication of people across such boundaries, affected by cultural factors and the density of relationships, are crucial for the creation and transfer of new ideas. In Massachusetts, connections and interactions between innovators and end users are extremely important to inspire new R&D and discover opportunities to apply R&D outcomes.

Innovation Infrastructure

This category includes the physical spaces in which innovators work and interact, such as laboratories, incubators, and venues which allow innovators from across the economy to come together. Innovation infrastructure also refers to the technologies and instruments that support R&D activities, including: high-speed Internet (access and bandwidth) and computing capacity; as well as the analytical instruments that support R&D activities in universities, hospitals, industries, and mission-oriented laboratories.

Demand

Demand for new capabilities is an important driver of innovation. In this context, we distinguish demand for new capabilities from the traditional marketplace demand for existing products and services (captured as Impacts). In Massachusetts, demand for innovative products, processes, and services comes from two sources. Firstly, and most importantly, from the marketplace. Comprised of businesses and consumers around the state, nation, and world, buyers of products and services created and sold by Massachusetts companies are vital sources of demand. The "demanding customer" both stimulates and motivates entrepreneurs and businesses to keep creating new or improved products, processes, and services. Secondly, the Federal government, particularly through its mission-oriented agencies such as the Department of Defense and the Department of Energy, is a crucial source of challenges as well as funding that sustains viability and pushes the technological frontier of many Massachusetts businesses.

Construction of the Indicators

About the Indicators

The indicators in the **Index of the Massachusetts Innovation Economy** are quantitative measures that allow performance comparisons with other leading regional innovation economies. The indicators examine long-term changes and trends in regional economic fundamentals, such as the education level of the workforce and manufacturing productivity, in addition to variables that are subject to short-term fluctuations, such as initial public offerings and venture capital funding. Indicators are selected to be measurable on an ongoing basis and derived from objective and reliable data sources. Appendix A describes in detail the construction of each indicator.

Benchmark Comparisons

Benchmark comparisons provide the context for understanding how Massachusetts is performing. The 2011 **Index** benchmarks Massachusetts against nine Leading Technology States (LTS) and the national average. The nine states chosen for comparison in the **2011 Index** are: California, Connecticut, Maryland, Minnesota, New Jersey, New York, North Carolina, Pennsylvania, and Virginia. Appendix A describes the methodology for selecting the LTS. To advance our understanding of Massachusetts' place in the global economy, the **Index** benchmarks Massachusetts against top performing nations where high quality international data are available.

Eleven Key Industry Clusters

The **2011 Index** monitors 11 industry clusters of the Commonwealth's Innovation Economy:

- Advanced Materials
- Bio-pharma and Medical Devices
- Business Services
- Computer and Communications Hardware
- Defense Manufacturing and Instrumentation
- Diversified Industrial Manufacturing
- Financial Services
- Healthcare Delivery
- Postsecondary Education
- Scientific, Technical, and Management Services
- Software and Communication Services

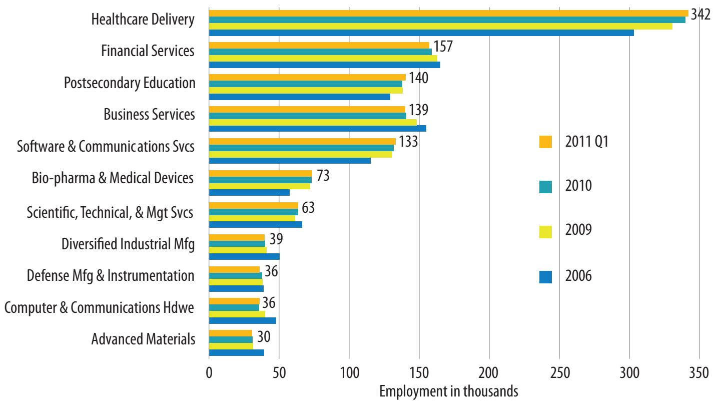
Together, these eleven Innovation Economy clusters account for 38.4% of employment in Massachusetts, including most of the highest paying jobs in the Commonwealth. Counting direct and indirect jobs, these industry clusters support more than half of all state employment. For purposes of the Index analysis indirect employment effects are not considered.

INDICATOR 1

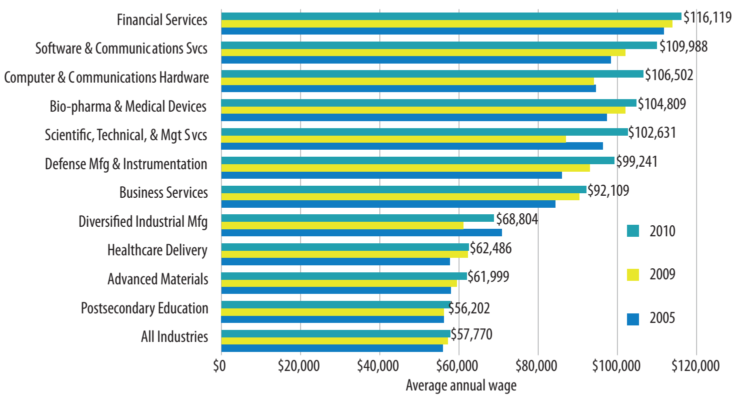
ECONOMIC IMPACT

Industry Cluster Employment and Wages

Employment by industry sector, Massachusetts, 2006, 2009, 2010, and 2011 Q1



Average annual wage by sector, 2010 dollars, Massachusetts, 2005, 2009, and 2010



Percent change in cluster employment, 2010 Q1 - 2011 Q1

	CA	CT	MD	MA	MN	NJ	NY	NC	PA	VA
Advanced Materials	1.7%*	-0.2%	1.0%*	-1.5%	3.6%	-1.6%	0.5%	0.3%	2.2%	-2.2%
Bio-Pharma & Medical Devices	1.1%	0.1%	-0.1%	1.2%	0.6%	-1.0%	0.3%	2.8%	-3.0%	0.5%
Business Services	2.3%	0.4%	3.7%	0.3%	2.3%	0.5%	1.3%	3.4%	2.7%	-0.8%
Computer & Comm Hrdwe	3.1%	2.1%	-5.1%*	1.9%	2.0%	-0.1%	-0.3%	-1.6%	3.2%	2.6%
Def Mfg & Instrumentation**	-1.5%	-0.4%	-5.3%	-0.5%	4.3%	-3.2%	1.7%	3.3%	1.8%	-0.4%*
Diversified Ind Mfg	2.8%	1.9%	-1.4%	0.5%	5.3%	1.5%	1.9%	4.8%	1.3%	-2.5%
Financial Services	-1.0%	-0.6%	0.9%	-1.3%	1.1%	-1.4%	2.4%	1.9%	-0.9%	0.4%
Healthcare Delivery	1.8%	1.8%	2.2%	1.6%	0.7%	1.4%	2.0%	0.3%	1.1%	1.3%
Postsecondary Education	-3.3%	3.9%	4.1%*	-0.6%	2.9%	1.9%	1.0%	1.0%	1.0%	4.4%
Scientific, Technical, & Mgmt Svcs	5.5%	6.3%	3.7%	3.0%	1.3%	4.9%	4.9%	4.3%	4.0%	4.9%
Software & Comm Svcs	3.5%	1.3%	0.5%	1.4%	1.3%	-2.3%	2.1%*	11.1%	-0.3%	1.1%
Total State Employment	1.0%	1.5%	1.8%	1.1%	1.5%	-0.3%	1.2%	1.4%	1.7%	1.5%
% of Total in Key Sectors, 2011 Q1	29.4%	35.9%	29.7%	38.4%	32.2%	31.8%	32.1%	30.6%	32.5%	30.4%

Source of all data for this indicator: Bureau of Labor Statistics' Quarterly Census of Employment and Wages
Note: Blue-shaded cells indicate job decline
* Due to undisclosed values by BLS, these figures are estimated based on historical data.
** In 2011 the BLS dropped NAICS code 33418 (Watch, clock and parts manufacturing) from the Defense Manufacturing & Instrumentation data, that subsector data is deleted from the 2010 data for comparison. This subsector accounted for 2,500 jobs in the LTS in Q1 2010, with the majority (1,440) of these employed in Massachusetts.

- Massachusetts continues to demonstrate a substantial 38.4% share of its total employment concentrated in the key sectors of the Innovation Economy.
- From the first quarter of 2010 to the first quarter of 2011, no Leading Technology State (LTS) lost employment in the combined key industry sectors of the Innovation Economy.
- Total wages paid in the key industry sectors of the Massachusetts Innovation Economy were 23% higher in 2010 than in 2005, a much larger increase than the 15% gain in the Massachusetts economy as a whole.

Why Is It Significant?

Increased employment concentration in technology and knowledge-intensive industry clusters can indicate competitive advantages for the Massachusetts Innovation Economy and potential for future economic growth. Typically, these clusters provide some of the highest paying jobs in Massachusetts.

How Does Massachusetts Perform?

Year-over-year employment in the overall Massachusetts economy was up 1.1% in the first quarter of 2011. This was the second smallest percent gain among the LTS, yet was only 0.7% behind the LTS leader, Maryland. Idaho (-.01%), New Mexico (-.04%), and New Jersey (-.32%) were the only states in the nation to lose jobs in this measure over that same period. In the key industry sectors of the Innovation Economy, Massachusetts gained 0.7% employment, the second smallest gain of any of the LTS. Among the LTS, only Minnesota did not lose of jobs in any of the key sectors for this time period.

A five-year comparison of employment in key industry sectors of the Massachusetts Innovation Economy reveals a 2.1% increase — 24,000 more people — in the first quarter of 2011 over the 2006 average. Employment gains during this interval were in Healthcare Delivery, Postsecondary Education, Bio-Pharma & Medical Devices, and Software & Communications Services. Jobs were lost in the other seven sectors of the Massachusetts Innovation Economy during the same interval.

Although inflation-adjusted wages declined in most sectors at some point between 2005 and 2010, when comparing only 2005 and 2010 data, inflation-adjusted wages were higher in every key sector in 2010 except Diversified Industrial Manufacturing (-2.8%). Of the eleven key sectors, the two with the largest increases over the five-year period were Defense Manufacturing & Instrumentation (15.8%) and Software & Communications Services (11.8%). Total aggregate wages paid in the key industry sectors of the Massachusetts Innovation Economy were 23% higher in 2010 than in 2005, a much larger increase than the 15% gain in the Massachusetts economy as a whole. Total aggregate wages paid in the key industry sectors of the Massachusetts Innovation Economy were 4.1% higher in 2010 than in 2009, a much larger increase than the 3.2% gain in the state's economy as a whole.

Occupations and Wages

- In terms of total jobs created in key sectors, Healthcare occupations come out on top with a positive net change of 33,810 jobs between 2005 and 2010.
- Massachusetts has a high concentration of employment in occupations that earn well above the national average.

Why Is It Significant?

The Massachusetts Innovation Economy supports middle- and high-wage jobs, thereby contributing to a higher standard of living throughout the Commonwealth. In specific occupational categories, employment concentrations higher than the national average indicate skill strengths particular to Massachusetts. Changes in occupational employment and wages suggest shifts in job content and skill utilization, as well as in the overall skill mix of the workforce across all industries.

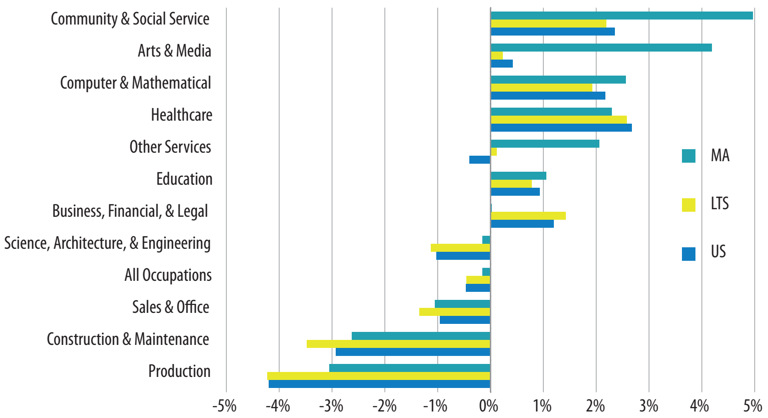
How Does Massachusetts Perform?

In 2010, Massachusetts ranked relatively high in the concentration of occupations in Healthcare; Community and Social Service; Computer and Mathematical; Arts and Media; and Science, Architecture, and Engineering.

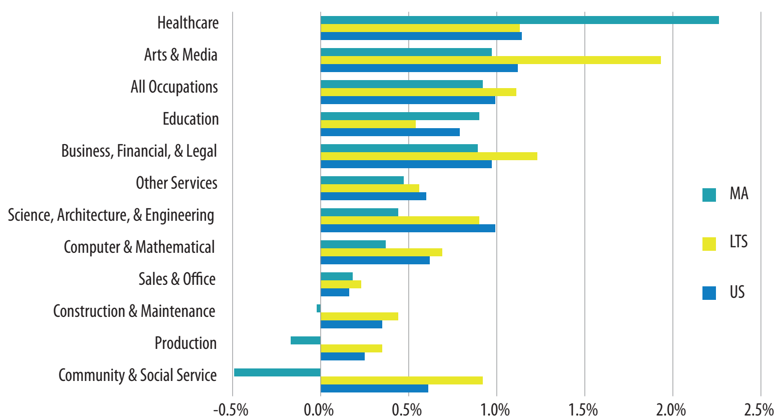
Between 2005 to 2010, net employment in Community and Social Services occupations increased the most, followed by Arts and Media, Computer and Mathematical; Healthcare, Other Services, and Education occupations. In terms of total jobs created in key sectors, Healthcare occupations come out on top with a positive net change of 33,810 jobs between 2005 and 2010.

Massachusetts has a high concentration of employment in occupations that earn well above the national average. This advantage is greatest for employees in Healthcare occupations who make 10.7% more on average than counterparts in other LTS. Healthcare witnessed the largest increase in inflation-adjusted wages between 2005 and 2010, growing by 11.8% in net terms, but still ranks second among the LTS behind California. The state's occupational mix contributes to above-average median household income. The average annual wage in Massachusetts in 2010 was $53,700, which is 9.6% greater than the LTS average ($49,000) and 21% above the national average ($44,400).

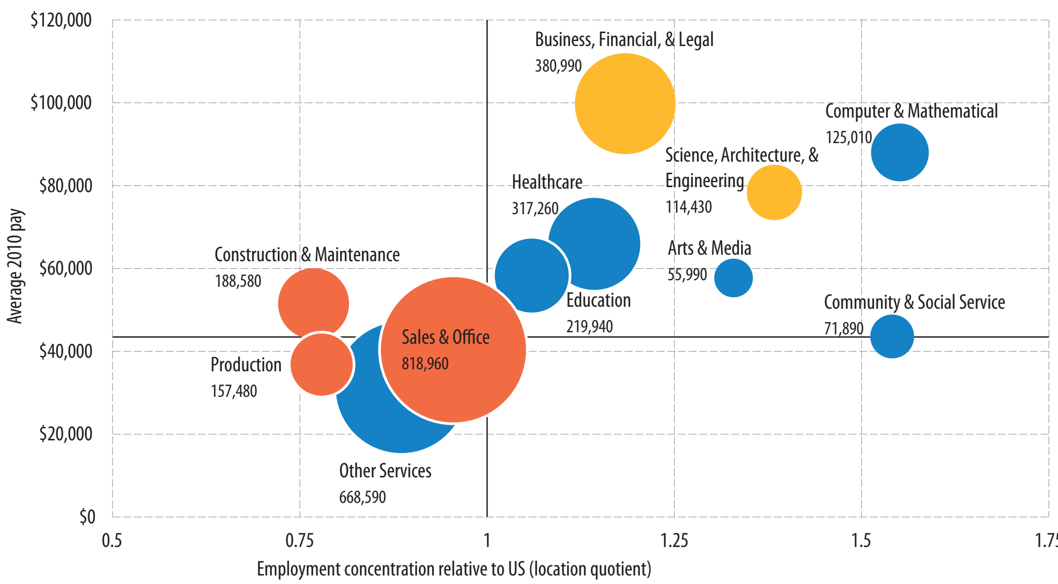
Average annual employment growth by occupation, Massachusetts, LTS, and US, 2005–2010



Average annual growth rate of real annual pay by occupation, Massachusetts, LTS, and US, 2005–2010



Occupations by employment concentration and annual pay, Massachusetts, 2010

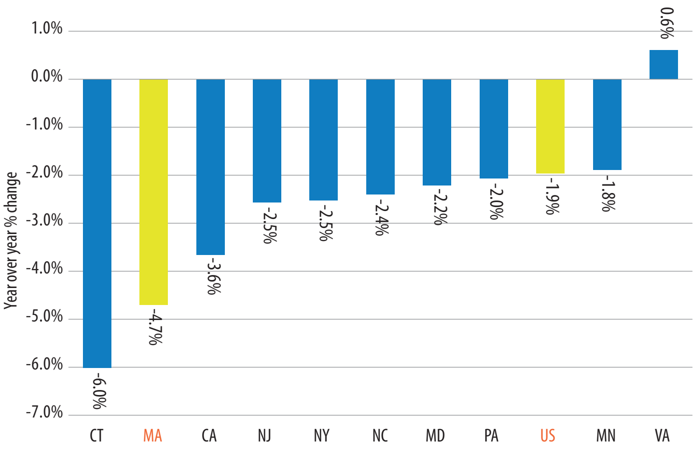


Circle size represents total employment
Solid horizontal line represents average national wage
Circle color represents year-over-year trend. Growing occupations appear in blue, stable in yellow, and shrinking in red.

Source of all data for this indicator: US Bureau of Labor Statistics, Occupational Employment Estimates

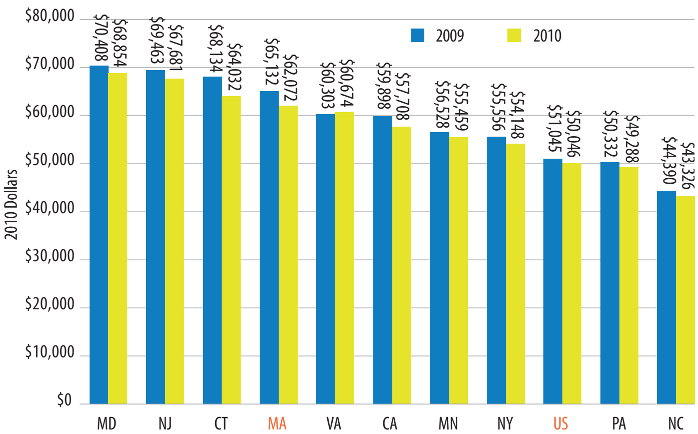
Household Income

Year over year percent change in median household income, LTS and US, 2010



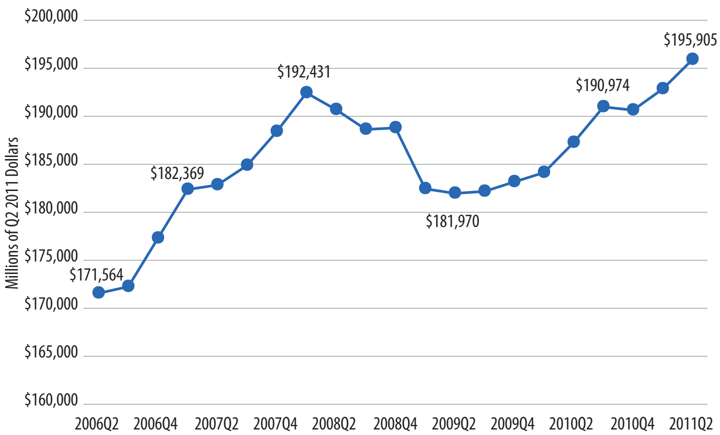
Source: US Census Bureau

Median household income, 2009 and 2010, LTS and US.



Source: US Census Bureau

Total wages and salaries paid, Massachusetts, Q2 2006 through Q2 2011



Source: Bureau of Economic Analysis

- Real median income in Massachusetts fell 4.7% in 2010, second only to Connecticut.
- Wages and salaries paid in the Commonwealth have been recovering since the first quarter of 2009, but have not yet resulted in a corresponding increase in median household income.
- Virginia was the only LTS to record an increase in median household income in 2010.

Why Is It Significant?

Household incomes that rise in inflation-adjusted dollars enable increases in the standard of living. Median household income tracks changes in the general economic condition of middle-income households and are a good indicator of prosperity. Significant changes in the Bureau of Economic Analysis' (BEA) estimates of wages and salaries for Massachusetts-based jobs traditionally can be a leading indicator for future changes in the standard of living because the two metrics generally move together.

How Does Massachusetts Perform?

With the exception of Virginia, which recorded the only gain, median household income fell in each of the LTS and the US from 2009 to 2010. In Massachusetts, median household income fell 4.7% to $62,072. Connecticut recorded the largest decline at 6.0%. Over the past nine years, the median income of Massachusetts' households has remained above the LTS average. In 2010, median household income in Massachusetts was 24.0% above the US average, and 6.4% above the LTS average.

After declining for four consecutive quarters beginning in early 2008, total wages and salaries paid in the Commonwealth and in the US stabilized in 2009, began to increase in 2010 and have continued to increase through 2011. Traditionally, the BEA's estimates of wages and salaries for Massachusetts-based jobs have proven to be a leading indicator for future change in Household Income. A wider inquiry would be needed to understand more completely which economic and demographic factors are responsible for a divergence in these two trends.

Productivity

- Manufacturing productivity in Massachusetts in 2010 increased in four of the five sectors measured by this indicator.
- Massachusetts has a manufacturing productivity advantage over the LTS in two of these five sectors.
- When reviewing productivity across all sectors, Massachusetts does relatively well, ranking third internationally.

Why Is It Significant?

Increasing productivity enables wage growth. It is defined as the value added per employee (labor productivity) or per unit of capital goods (capital productivity). Firms with high labor productivity create comparatively higher levels of commercial value, have relatively fewer employees, or a combination of the two. In order to achieve increases in the level of labor productivity, individuals and organizations must innovate in ways that increase the value of their products or services, or make the business processes more efficient.

Manufacturing value added per manufacturing employee is a measure of manufacturing labor productivity. Increases in manufacturing productivity are essential to avoiding a ‘race to the bottom’ of the level of manufacturing wages among competitors or the loss of jobs to overseas production.

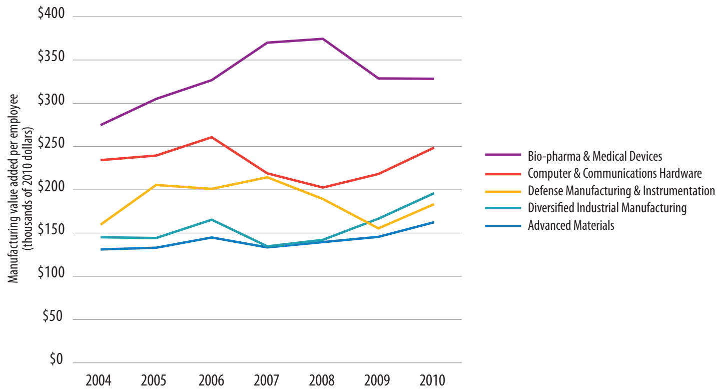
How Does Massachusetts Perform?

From 2005 to 2010, the key industry sector in Massachusetts with the fastest manufacturing labor productivity growth was Diversified Industrial Manufacturing, in which productivity grew by 35.9%. The Diversified Industrial Manufacturing sector had the highest productivity relative to the LTS average in 2010. The Advanced Materials sector had the second highest rate of manufacturing productivity growth (22.1%) from 2005 to 2010. In contrast, productivity declined in Defense Manufacturing & Instrumentation during this interval as manufacturing value added declined faster than manufacturing employment. In 2010, the Bio-pharma and Medical Devices sector had the lowest productivity relative to the LTS average.

Productivity in most manufacturing sectors in Massachusetts lagged the LTS and U.S. averages during 2010. The state did have a manufacturing labor productivity advantage over the LTS in two of these five sectors, Diversified Industrial Manufacturing and Computer & Communications Hardware. Relative to the U.S. overall, Massachusetts had a manufacturing labor productivity advantage in one sector, Diversified Industrial Manufacturing.

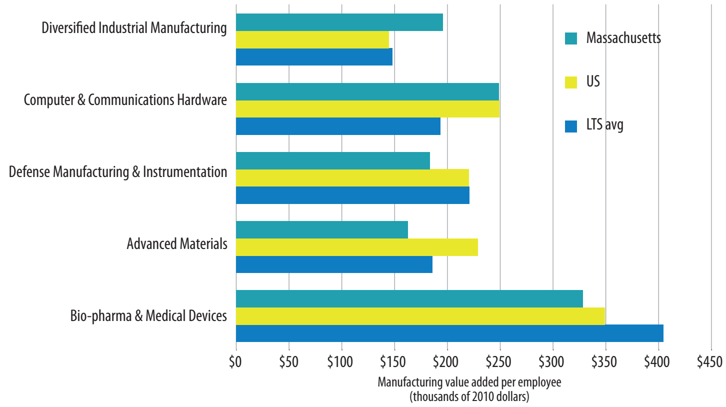
Massachusetts also ranks well internationally in terms of productivity. For example, Massachusetts ranks third in the world as measured by GDP per employed resident. By this measure, productivity grew the fastest in Canada and Norway from 2004 to 2010. Luxembourg and Norway had the highest productivity in 2010.

Manufacturing labor productivity by sector, Massachusetts, 2004 to 2010



Source: US Census Bureau, Annual Survey of Manufactures

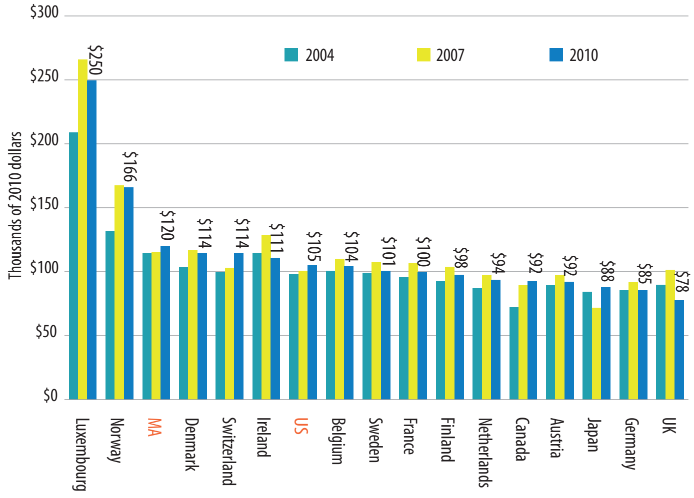
Manufacturing labor productivity by sector, Massachusetts, LTS, and US, 2010



Source: US Census Bureau, Annual Survey of Manufactures

INTERNATIONAL

GDP per employed resident, international, 2004, 2007, and 2010



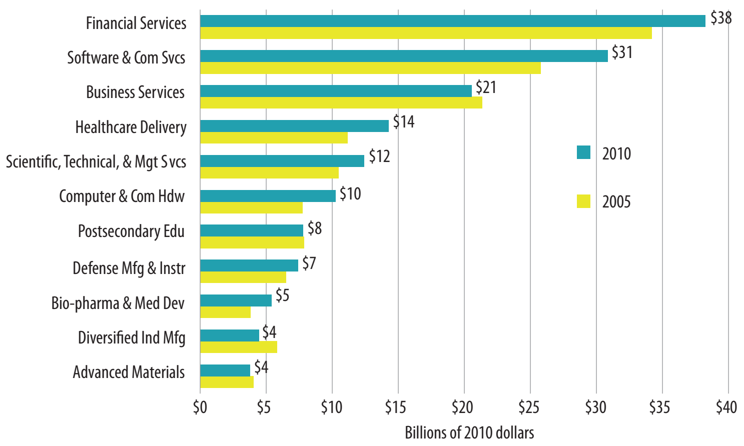
Source: Bureau of Labor Statistics, the World Bank, and the International Labor Organization

INDICATOR 5

ECONOMIC IMPACT

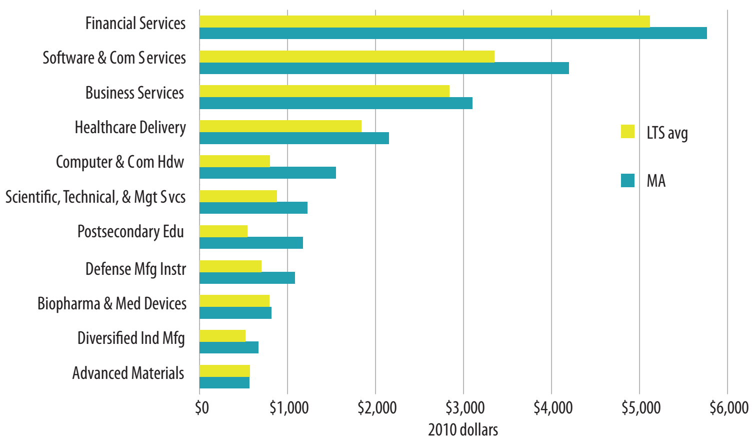
Industry Output and Manufacturing Value Added

Industry output by sector, Massachusetts, 2005 and 2010



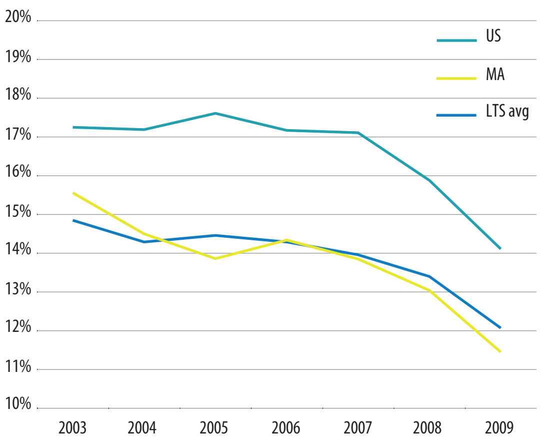
Source: Moody's Economy.com

Industry output per capita, Massachusetts and LTS, 2010



Source: Moody's Economy.com

Manufacturing value added as a percent of GDP, Massachusetts, LTS, and US, 2003-2009



Source: US Census Bureau, Annual Survey of Manufactures

- Between 2005 and 2010, increases in the output of seven of Massachusetts' key industry sectors outweighed decreases in the remaining four, resulting in a net increase of $16.6 billion (12.0%).
- On a per capita basis, Massachusetts outperformed the LTS average in output in 2010 in all of the key industry sectors except Advanced Materials.
- Between 2008 and 2009, manufacturing value added declined more in Massachusetts (-13.4%) than the LTS (-11.2%) and U.S. (-12.7%) averages

Why Is It Significant?

Industry output, the market value-added of goods and services produced in a sector, provides insight into the performance of industry sectors over time. Due to inherent differences in the way industry output is calculated in different sectors, it is important, however, not to interpret this measure as an assessment of the importance of one industry relative to another. Manufacturing value-added is a measure of the economic value created by manufacturers across industry sectors. It is calculated by subtracting the costs of primary factor inputs for manufacturing from the value of the final product.

How Does Massachusetts Perform?

The largest increases in industry output from 2005 to 2010 in Massachusetts occurred in Bio-pharma & Medical Devices (40.9%), Computer and Communications Hardware (32.1%), and Healthcare Delivery (27.9%). Declines in industry output were greatest in Diversified Industrial Manufacturing (-23.6%), Advanced Materials (-7.1%), and Business Services (-3.7%). Overall, the increases in the output of Massachusetts' key industry sectors outweighed the decreases, resulting in a net gain of $16.6 billion.

On a per capita basis, Massachusetts outperformed the LTS average in industry output in 2010 in all of the key industry sectors except Advanced Materials. Moreover, the Commonwealth ranked first among the LTS in per capita industry output in one sector, Postsecondary Education, and was among the top three LTS in all but Advanced Materials, Business Services, and Bio-pharma & Medical Devices.

In 2009, Massachusetts manufacturing value added was 11.5% of GDP; this represents a decline from 14.5% five years earlier in 2004. Declines between 2007 and 2009 appear particularly steep, partly as a result of adjusting for inflation since there was also a decline in the Consumer Price Index. However, even without adjusting for inflation, between 2008 and 2009 manufacturing value added declined more in Massachusetts (-13.4%) than the LTS (-11.2%) and U.S. (-12.7%) averages.

Manufacturing Exports

- Manufacturing exports as a percentage of GDP increased in Massachusetts from 6.1 % in 2009 ($22.1 billion) to 6.5% in 2010 ($24.8 billion).
- Canada replaced Great Britain as Massachusetts' top export destination.
- Massachusetts exports to China grew by nearly 60%, led by a large increase in the exports of Machinery.

Why Is It Significant?

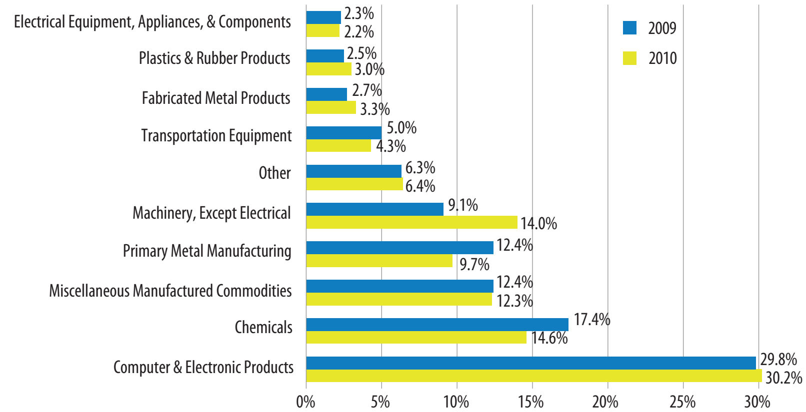
Manufacturing exports are an indicator of the Commonwealth's global competitiveness. Selling into global markets can help bolster growth in sales and employment, and increase market share for innovation-intensive companies. In addition, diversity in target export markets and product categories can create an offset or hedge against economic downturns in different regions in the world. Also, because manufacturing represents 9.5% of all private sector jobs in the Commonwealth, it is noteworthy that 22.2% (2 of 9) of manufacturing jobs are tied to exports.

How Does Massachusetts Perform?

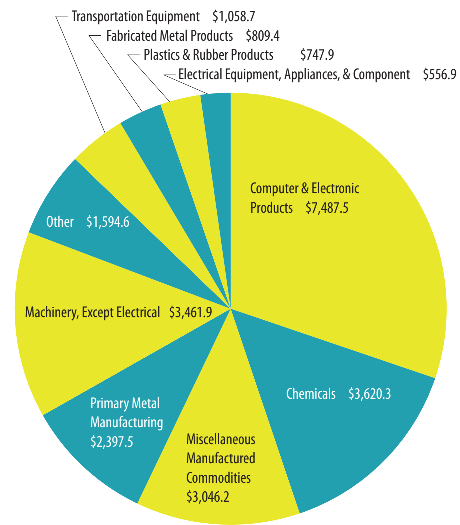
After decreasing by $1.6 billion over seven quarters (from 1Q 2008 to 3Q 2009), Massachusetts' exports rebounded by $1.4 billion (27.3%) in the following eight quarters. All LTS experienced this trend. Exports increased the fastest in New York at 54.4%, followed by New Jersey at 36.2% during this time period. Relative to state GDP, in 2010 Massachusetts was the second largest exporter ($24.8 billion, 6.5% of GDP) among the LTS after California ($124.6 billion, 6.6% of GDP).

The distribution of Massachusetts' top export categories has held mostly steady from 2004 through 2010. In 2010, 44.8% of manufacturing exports from Massachusetts were chemicals and computer and electronic products. In 2010, Canada was the largest destination for Massachusetts' exports, followed by Great Britain. China moved up from 7th to 3rd place in 2010 as Massachusetts exports to China grew by nearly 60%.

Distribution of Massachusetts manufactured exports, 2009 and 2010

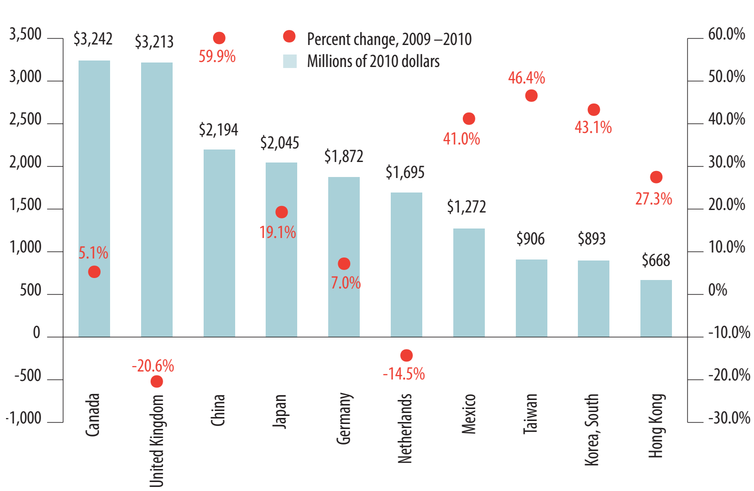


Distribution of manufacturing exports, in millions, Massachusetts, 2010

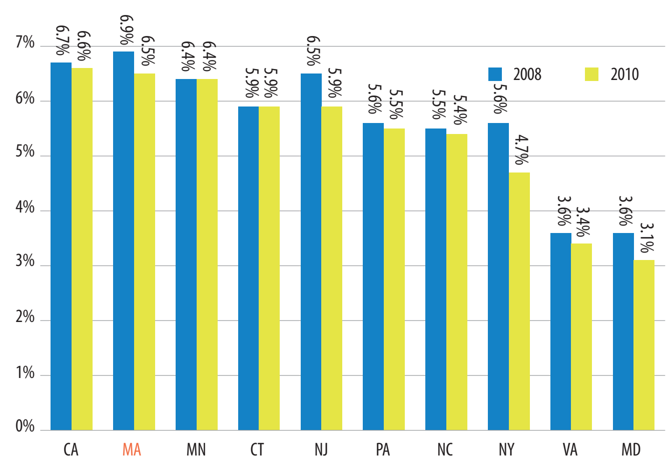


INTERNATIONAL

Export value by top foreign trade destination, Massachusetts, 2010



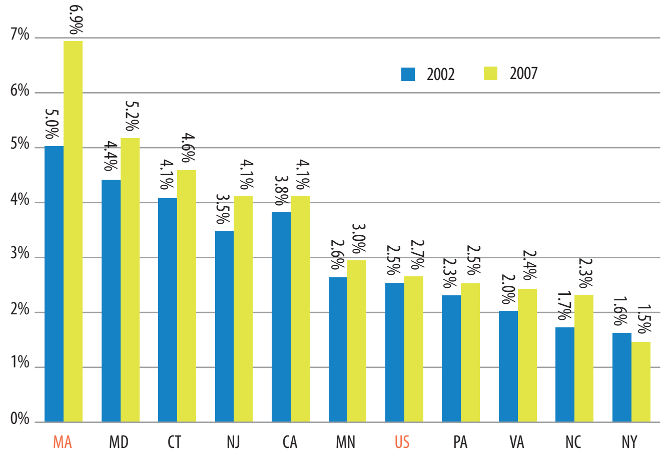
Manufacturing exports as a percent of GDP, 2008 and 2010



Source of all data for this indicator: WiserTrade.org

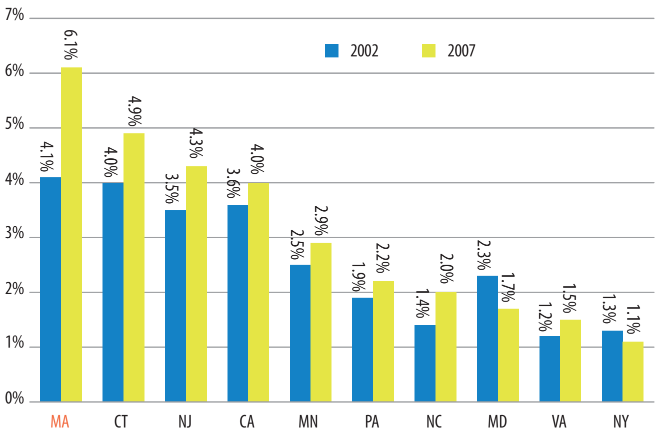
Research and Development Performed

R&D as a percent of GDP, LTS, 2002 and 2007



Source: National Science Foundation

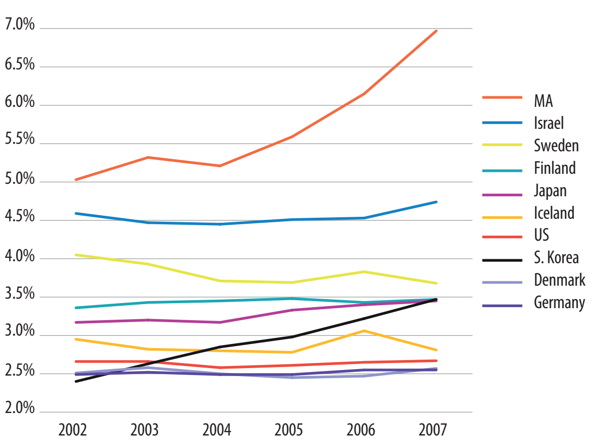
Industry-performed R&D as a percent of private-industry output, LTS, 2002 and 2007



Source: National Science Foundation and the Bureau of Economic Analysis

INTERNATIONAL

R&D performed as a percent of GDP, international and Massachusetts, 2002-2007



Source: United Nations Educational, Scientific and Cultural Organization (UNESCO) and the National Science Foundation

- Massachusetts has the highest and fastest growing R&D intensity among the LTS and R&D-leading countries measured by R&D as a percent of GDP.
- Massachusetts leads the LTS in industry-performed R&D as a percent of private industry output.

Why Is It Significant?

R&D performed in Massachusetts is an indicator of the size of the science and technology enterprise. Even though not all new ideas or products emerge from defined R&D efforts, R&D data provide a sense of a region's capacity for knowledge creation.

How Does Massachusetts Perform?

Massachusetts has the most R&D intensive economy of the LTS and a more R&D intensive economy than leading countries, as measured by R&D as a percent of GDP. In 2007, $25.4 billion dollars of R&D was performed in Massachusetts.

The average annual growth rate of R&D among the LTS, as a percent of GDP from 2002 to 2007, was highest in Massachusetts, growing an average of 6.9% annually, followed closely by North Carolina at 6.8%. Over these five years, R&D as a share of GDP rose in all of the LTS except New York.

Massachusetts also leads in industry-performed R&D as a percent of private industry output. Massachusetts' industry became increasingly R&D intensive from 2002 to 2007 during which time R&D intensity grew from 4.1% to 6.1% of output. This is the fastest growth among the LTS, once again followed closely by North Carolina, where the R&D intensity of industry grew from 1.4% to 2.0% of industry output.

Performers of R&D

- R&D expenditures in industry increased by 64% in absolute terms between 2002 and 2007. Among the LTS, this growth is second to North Carolina, where there was a 72% increase. Industry is responsible for the bulk of R&D expenditures in Massachusetts.
- Massachusetts leads the LTS in R&D expenditures per capita by industry and nonprofit research institutions.

Why Is It Significant?

The distribution of R&D expenditures by type of performer illustrates the relative importance of different kinds of organizations performing R&D in an innovation ecosystem, as well as providing insight into the mix of basic research, applied research, and development performed. Nationally, 75% of the research by universities and colleges is classified as basic and only 4% as development. In contrast, 76% of research by industry is classified as development and only 4% as basic. Federal agencies tend to perform more applied research and less development, while non-profits tend to perform more basic and applied research. A mix of R&D performers and types of research is required to cover the pathway from knowledge creation to commercialization in an innovation ecosystem.

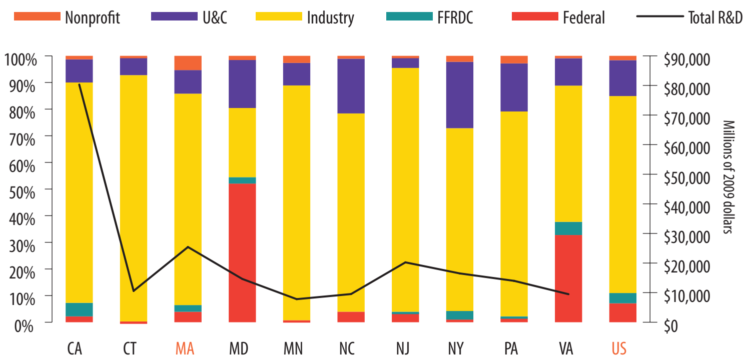
How Does Massachusetts Perform?

National data show that approximately 7% of all R&D is performed by federal agencies, 71% by industry, 13% by universities and colleges, 4% by non-profit organizations and 5% by Federally Funded R&D Centers (FFRDC's). Massachusetts conforms to the national pattern, as do all the LTS except two, where the federal government conducts more than 30% of R&D (Maryland with 52.0% and Virginia with 32.7%).

Both in absolute terms and as a proportion of the total, industry's expenditures in the state's R&D enterprise grew steadily between 2002 and 2007. It increased 64% in absolute terms, from 72% to 79% as a proportion of the total. In the same period R&D expenditures by universities, colleges and non-profit institutions in Massachusetts grew by 10%.

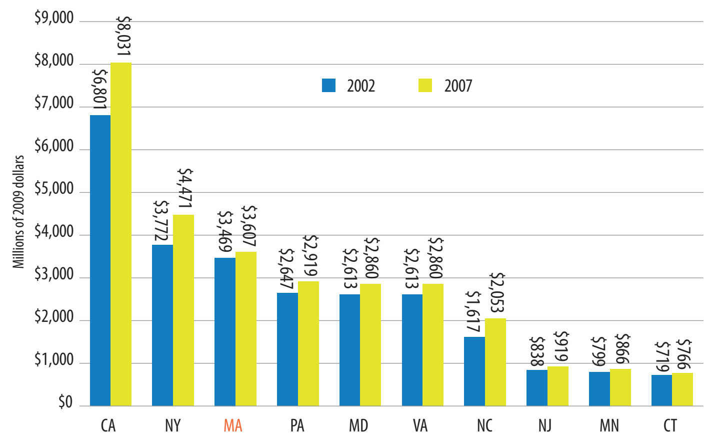
Among the LTS, Massachusetts is unique in the high proportion of R&D conducted by nonprofit institutions. In 2007, they conducted a total of $1.4 billion of research in Massachusetts—higher than in any other LTS, even without adjusting for the size of the economy. This is $209 per capita, more than five times higher than Maryland which is second in this measure among the LTS. Nonprofit research institutions include the Commonwealth's health centers such as the Dana-Farber Cancer Institute, as well as organizations such as the Broad Institute, Charles Stark Draper Laboratories and the Woods Hole Oceanographic Institution, but exclude colleges and universities.

Distribution of R&D by performer, LTS and US, 2007



Source: The National Science Foundation

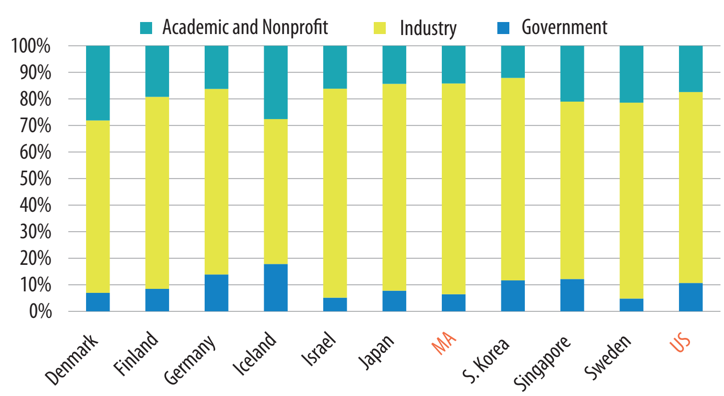
R&D performed by universities, colleges, and nonprofit research institutes, 2002 and 2007



Source: The National Science Foundation

INTERNATIONAL

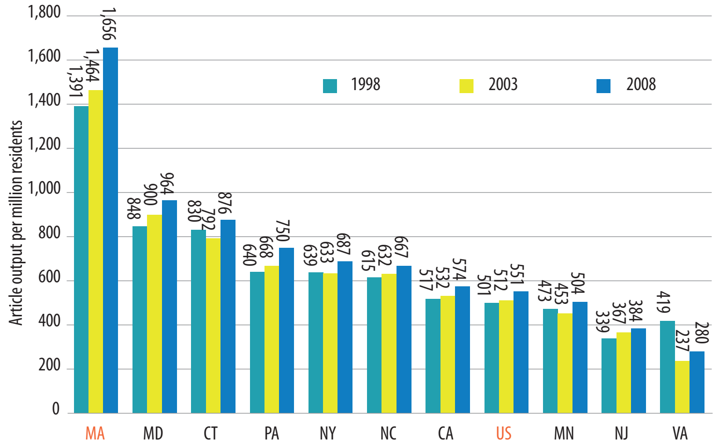
Distribution of R&D by performer, international and Massachusetts and US, 2007



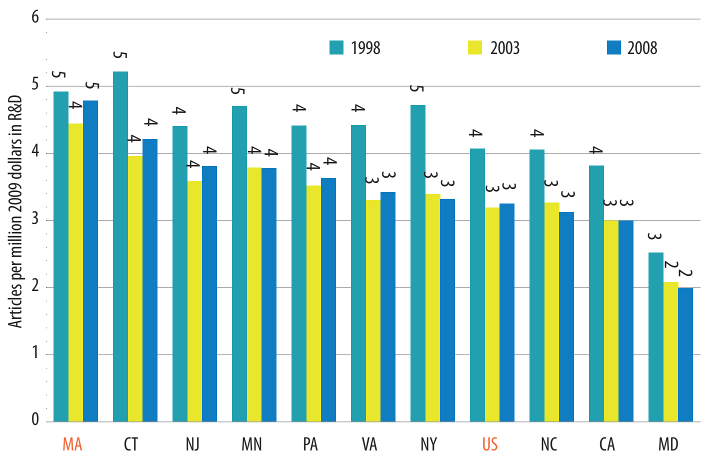
Source: United Nations Educational, Scientific, and Cultural Organization (UNESCO)

Academic Article Output

Science and Engineering (S&E) Academic article output per million residents, LTS and US, 1998, 2003, and 2008

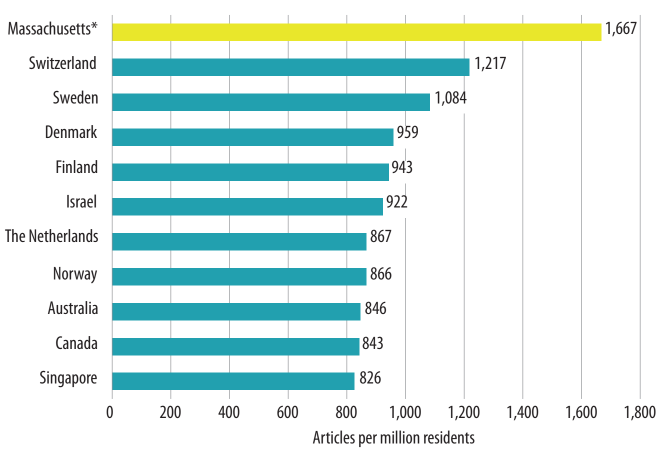


Science and Engineering (S&E) Academic article ouput per million academic R&D dollars, LTS and US, 1998, 2003, and 2008



INTERNATIONAL

S&E articles per million residents, 2007, international



*Only 2008 data available for Massachusetts, and 2007 data available for international comparison.
Source for all data for this indicator: The National Science Foundation

- In 2008 Massachusetts had the highest number of academic articles published per capita among the LTS and internationally.
- Productivity in academic articles (articles published per million academic R&D dollars) is higher in Massachusetts than the other LTS.

Why Is It Significant?

In contrast to R&D expenditures, which are an input to research, academic article publication is a measure of research output and represents the most common form of codified dissemination of research results. This is also an important productivity measure as well as an indicator of Massachusetts researchers' participation in the global science and engineering conversation.

How Does Massachusetts Perform?

Massachusetts had the highest number of academic articles published per capita among the LTS in 2008, a reflection of the intensity of knowledge production in the Commonwealth's research enterprise. This metric is 72% higher in Massachusetts than in Maryland, which is second among the LTS. Internationally, Massachusetts also has the highest per capita output of academic articles.

Measures of research productivity are less differentiated among the LTS. Nevertheless, Massachusetts researchers are among the most productive of the LTS, based on the number of academic articles published per academic R&D dollar.

Patenting

- Patents granted to Massachusetts inventors increased 33.2% in 2010 from 2009, the largest year-to-year percentage increase in Massachusetts for at least 45 years.
- Massachusetts was ranked 5th in the US for number of patents granted in 2010, but led the LTS in the number of patents granted per capita this year.

Why Is It Significant?

Patents are the leading form of legal codification and ownership of innovative thinking and its application. A patent award is particularly important for R&D-intensive industries when the success of a company depends on its ability to protect inventive products resulting from investments in R&D. High levels of patenting activity indicate an active R&D enterprise combined with the capacity to codify and translate research into unique technology with commercial potential. US Patent and Trademark Office (USPTO) patents represent one-fifth of global patents. To protect invention from imitators, a new patent must be filed with each country (or region) in which a company wishes to market a new product or service.

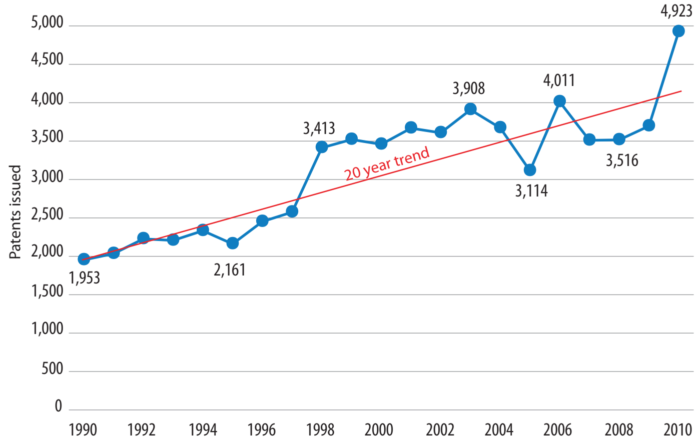
How Does Massachusetts Perform?

The total number of patents granted by the USPTO to Massachusetts' inventors rose an extraordinary 33.2% to 2010 from 2009. Patenting has remained relatively high in Massachusetts since 1998 when the number of patents granted jumped to 3,413 from 2,575. The sharp decline in patents granted in 2005 is consistent with national trends and is most likely due to slowdowns in the processing of patent applications, especially since the number of applications for patents was on pace that year. The pace of patents issued in Massachusetts has since picked up with patents granted in 2010 climbing to 4,923 from 3,696, an increase of 1,227 or 33.2%. This marks the largest year-to-year increase that Massachusetts has had in at least several decades. It's important to note the very large increases may also be an aberration reflecting the pace of processing at the USPTO. Over the past ten years, patents issued by California and Virginia inventors increased the fastest, both at an average annual growth rate of 5.2%, followed by Minnesota at 4.6%, Massachusetts at 4.5%, and New York at 4.3%. Patenting activity did not decline in any of the LTS in 2010, with Pennsylvania growing the slowest at 0.5% and Connecticut next at 0.9%.

Massachusetts leads the LTS in the number of patents granted on a per capita basis in 2010. Unlike previous years, where Massachusetts had only a narrow lead over several LTS, Massachusetts now has a sizable lead over the closest LTS, New York and California, by 24.3% and 26.9% respectively.

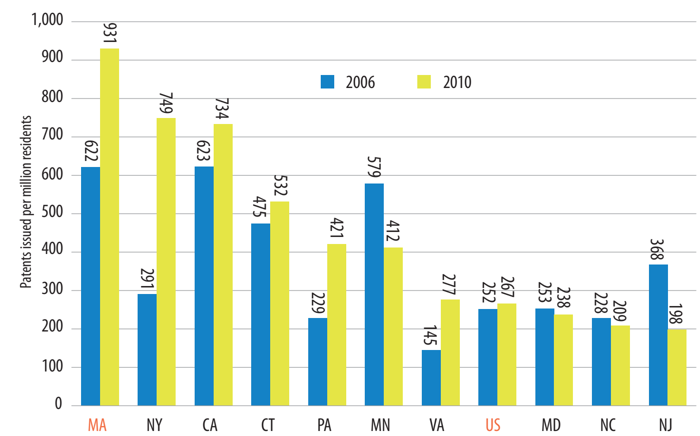
Internationally, Massachusetts ranked 7th (after Sweden, Switzerland, Finland, Israel, South Korea, and Netherlands) in the number of patents relative to GDP under the Patent Cooperation Treaty administered by the World Intellectual Property Organization in 2010. The United States, as a whole, ranked 14th that year.

US Patent and Trademark Office patents issued, Massachusetts, 1990-2010



Source: US Patent and Trademark Office

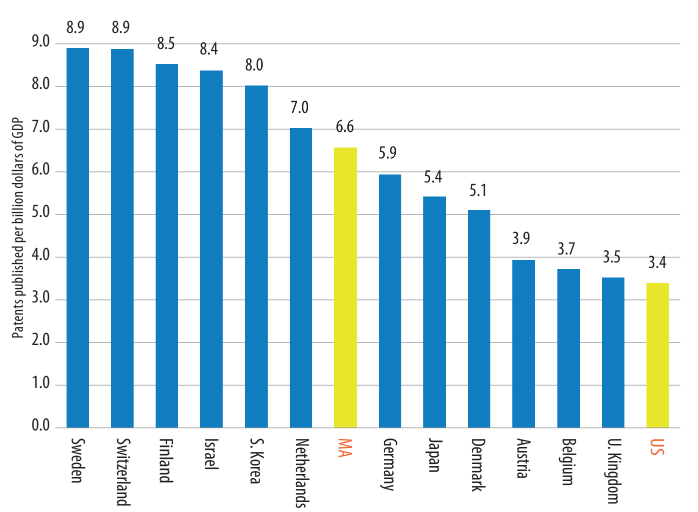
US Patent and Trademark Office patents issued per million residents, LTS, 2006 and 2010



Source: US Patent and Trademark Office

INTERNATIONAL

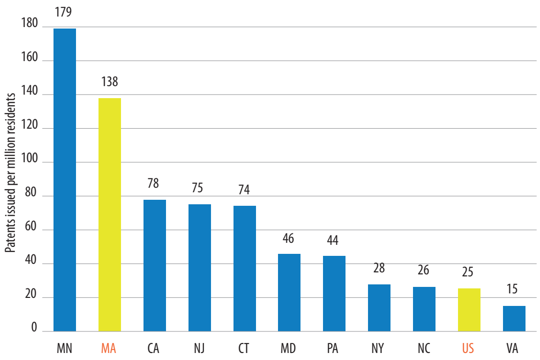
Patents published under the Patent Cooperation Treaty per billion dollars of GDP, international and Massachusetts, 2010



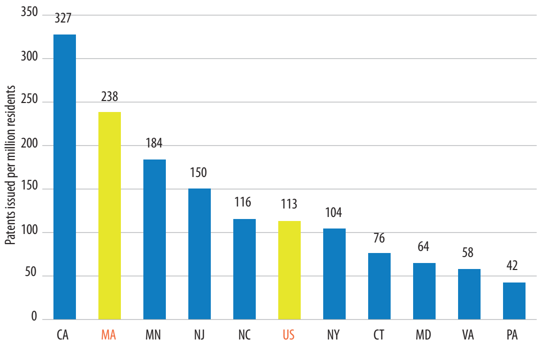
Source: World Intellectual Property Organization

Patenting by Field

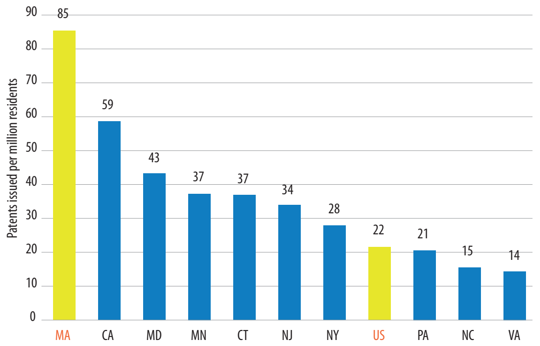
Drugs and medical patents per million residents, LTS, US, 2010



Computer and communications patents per million residents, LTS, US, 2010



Analytical instruments and research methods patents per million residents, LTS, US, 2010



- Massachusetts excels in patenting per capita across a spectrum of patent classes relevant to key sectors of the Innovation Economy.
- Massachusetts is first among the LTS in analytical instrument patents and ranks second in research methods, business methods, computers and communications, and drugs and medical patents.

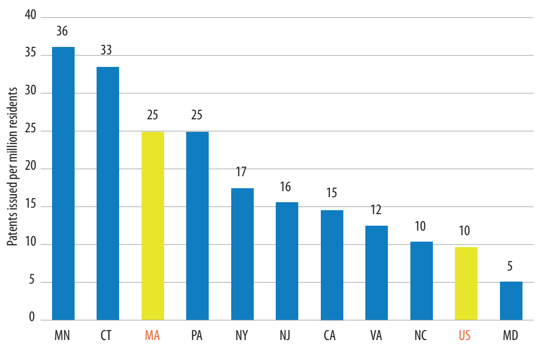
Why Is It Significant?

Measuring the amount of patenting per capita by technology class indicates those fields in which Massachusetts' inventors are most active and suggests comparative strengths in knowledge creation, which is a vital source of innovation. The patent categories in this comparison are selected and grouped on the basis of their connection to key industries of the Massachusetts Innovation Economy.

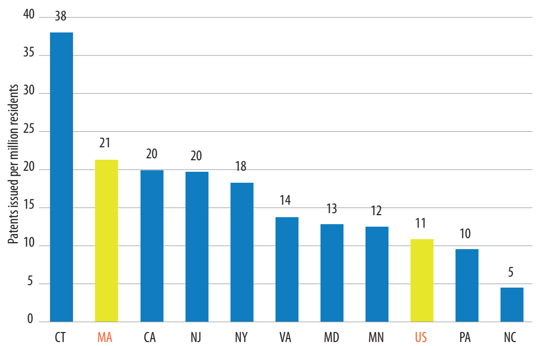
How Does Massachusetts Perform?

The breadth and depth of Massachusetts' strength in original knowledge creation are evident from its first, second, or third place rankings among the LTS for patents per capita across a broad range of fields. On a patents per capita basis, the Commonwealth ranks first among the LTS in analytical instruments and second among the LTS in business methods, computers and communications, drugs and medical, and research methods. Massachusetts places third in patents per capita for advanced materials. None of the LTS appears in the top three in all five of the patent classes measured in this indicator.

Advanced materials patents per million residents, LTS, US, 2010



Business method patents per million residents, LTS, US, 2010



Source of all data for this indicator: US Patent and Trademark Office

Technology Licensing

- In 2009, Massachusetts reversed a two-year decline, increasing the number of technology licenses and options executed by in-state institutions by 10.9% (5,771 total).
- Massachusetts' universities, hospitals, and nonprofit research institutes led the LTS in the number of licenses and options executed in 2009.
- Universities in Massachusetts reached a 14-year high in technology licensing and options revenue, bringing in $159.5 million in 2009.

Why Is It Significant?

Technology licenses provide a vehicle for the transfer of codified knowledge in the form of intellectual property (IP) from universities, hospitals, and nonprofit research organizations to companies and entrepreneurs seeking to commercialize the technology. License royalties are evidence of the perceived value of IP in the marketplace and are typically based on revenue generated from the sales of products and services using the licensed IP or from the achievement of milestones on the path of commercialization. Increases in royalty revenue are important, validating the original research and innovation, and can be reinvested in additional R&D. This promotes and reinforces incentives at universities, teaching hospitals, and nonprofit research institutes to undertake new research.

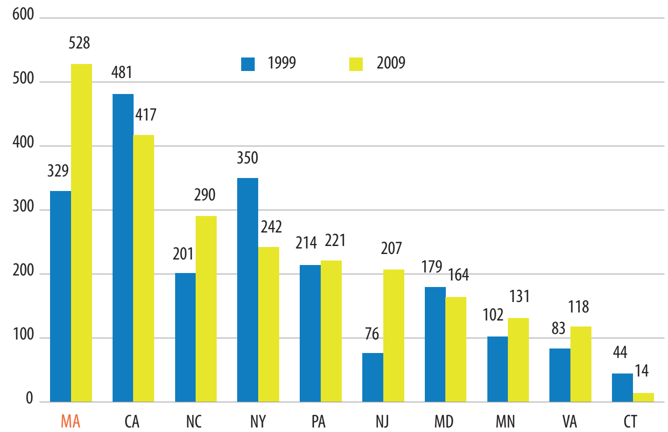
How Does Massachusetts Perform?

Massachusetts' universities, hospitals, and other nonprofit research institutes have long-established track records in executing IP licenses and options, and both the number and dollar value of these agreements have increased. Even without adjusting for the size of the LTS' respective economies, Massachusetts' universities, hospitals, and nonprofit research institutes led in the number of technology licenses and options executed in 2009 as in prior years.

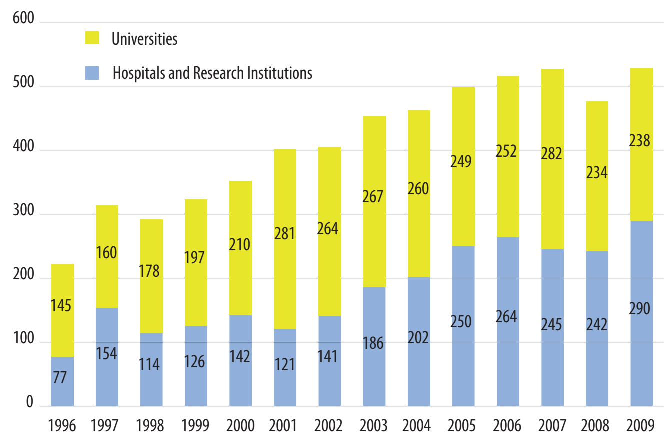
From 1999 to 2009, IP licensing grew fastest in New Jersey where the number of licenses increased at an average yearly rate of 21% (from 76 to 207), followed by North Carolina and Virginia, both with an average annual increase of 12% (North Carolina from 201 to 290 and Virginia from 83 to 118). In Massachusetts, the number of licenses increased at an average annual growth rate of 5.4% during that decade, but from 2007 to 2008 the number of licenses dropped 10% from 527 to 476. Most of the decrease in licensing activity occurred at Massachusetts' universities. The number then again grew in Massachusetts by 11% to 528 in 2009.

Licensing revenue at Massachusetts' universities increased 5.4% in 2009 to $162 million, reaching a 13-year high. After spiking in 2006 ($386.7 million) and 2007 ($402.3 million), 2008 licensing revenue ($81.3 million) at hospitals and research institutions dropped to 2003 levels but saw a 10% growth (+ $8 million) in 2009. Ninety-nine percent of the spike from 2005 to 2007 was attributed to Massachusetts General Hospital (MGH), as MGH sold its rights to royalties on foreign sales of the arthritis drug Enbrel in 2007, resulting in $284 million of licensing income.

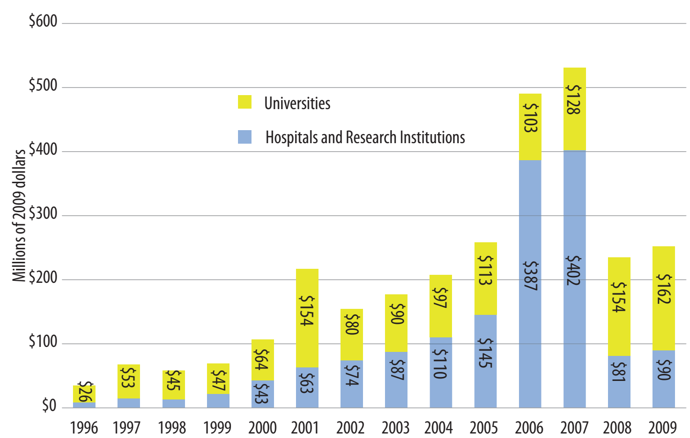
Technology licenses and options executed, LTS, 1999 and 2009



Technology licenses and options executed by major universities, hospitals, and other nonprofit research institutions, Massachusetts, 1996-2009



Technology licensing revenue received by major universities, hospitals, and nonprofit research institutes, Massachusetts, 1996-2009

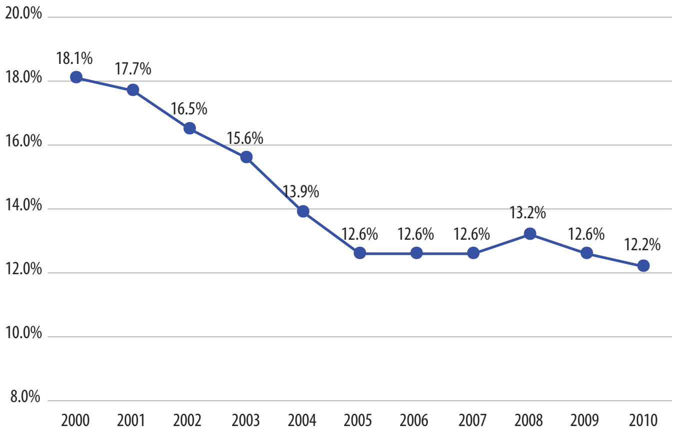


Source of all data for this indicator: Association of University Technology Managers

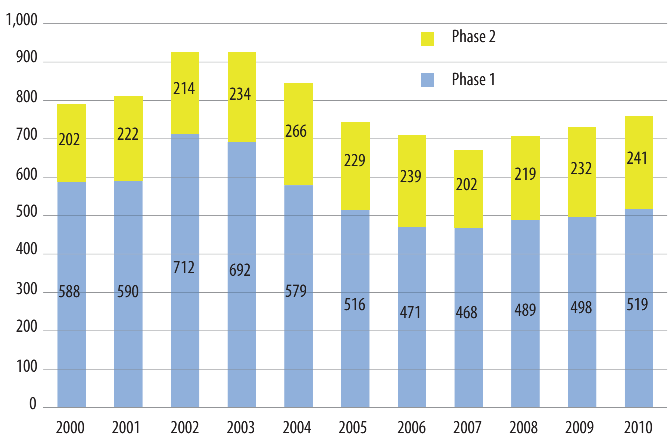
INDICATOR 13

Small Business Innovation Research Awards

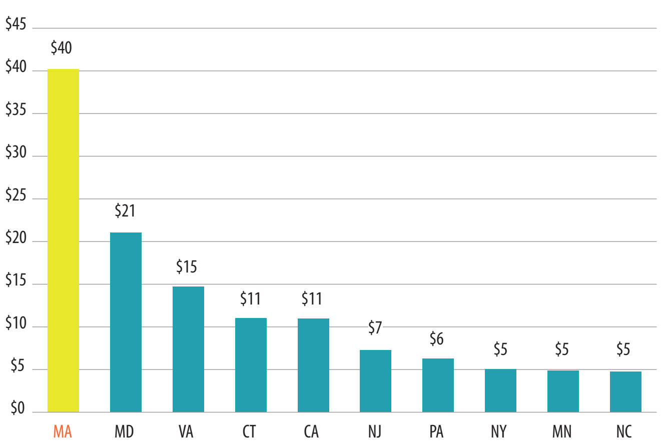
Massachusetts' share of number of SBIR awards, 2000–2010



SBIR awards to companies by phase, Massachusetts, 2000-2010



Dollar value of SBIR awards per capita, LTS, 2010



Source for all data for this indicator: US Small Business Administration (SBA)

- Small companies brought $267 million into the Commonwealth for technology development in 2010 by competing for SBIR awards—a decrease of $1.4 million (-0.5%) from 2009.
- While Massachusetts' small companies continue to excel in competing for SBIR funding, the state's share of SBIR awards has fallen from 18.1% to 12.2% over the past decade.

Why Is It Significant?

The Small Business Innovation Research (SBIR) Program is a highly competitive federal grant program that enables small companies to conduct proof-of-concept (Phase I) research on technical merit and idea feasibility and prototype development (Phase II) building on Phase I findings.

Unlike many other federal research grants and contracts, SBIR grants are reserved for applicant teams led by for-profit companies with fewer than 500 employees. The program is intended to address the technology needs of federal agencies while encouraging companies to profit from the commercialization of research. Participants in the SBIR program are often able to use the credibility and experimental data developed through their research to develop commercial products and to attract strategic partners and investment capital.

How Does Massachusetts Perform?

In 2010, Massachusetts' small businesses were awarded 12.2% of total SBIR funds. Massachusetts continues to rank second to California in absolute terms (dollar value and number of awards), but, in terms of the amount of funding per capita, Massachusetts continues to be the leader nationwide. Massachusetts' share of SBIR funds awarded, however, has continued to decline, falling from 18.1% in 2000 to 12.2% in 2010.

From 2007 to 2010, both Phase I and Phase II awards to Massachusetts' companies increased. The number of Phase II awards grew faster, at an average annual growth rate of 6.1% compared to 3.5% for Phase I awards. The Department of Defense (DOD) and Health and Human Services (HHS) are the largest sources of SBIR awards for the Commonwealth. Massachusetts companies ranked either first or second in the nation in terms of the number of Phase I and Phase II awards granted by each major (at least 50 Phase I awards) SBIR funding agency.

Regulatory Approval of Medical Devices and Pharmaceuticals

- Massachusetts companies received two medical device pre-market approvals in 2010, second only to California, which received six.
- Massachusetts ranks second in total number of new drug approvals (4.5), and is in a three-way tie for first in number of biologic approvals (1).

Why Is It Significant?

The U.S. Food and Drug Administration (FDA) classifies medical devices by two categories during the approval process: pre-market approvals (PMAs) and pre-market notifications, known as 510(k)s. PMA is the designation for the more sophisticated, newly-developed devices, while 510(k) is a classification for less sophisticated instruments or for simple improvements to existing products or functional equivalents. These approvals track innovation in medical device design and manufacturing, and often indicate important relationships with teaching and research hospitals where many of these devices undergo clinical investigation and trial.

New Drug Applications (NDAs) measure a commercially important outcome from years of research and development. Biologics, which include drugs, vaccines, blood products, and therapies created through biological processes, are of particular importance in today's market. They hold the promise of new approaches for treating cancer, infectious diseases, autoimmune disorders, and other medical conditions.

How Does Massachusetts Perform?

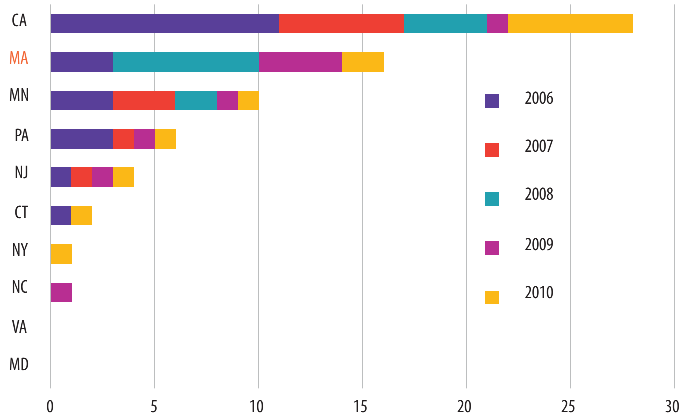
Massachusetts regularly ranks first or second among the LTS, in both absolute and relative terms, in medical device approvals and notifications and new drug approvals. This reflects the Commonwealth's strong life sciences and healthcare technology sectors.

Among the LTS, Massachusetts ranked second behind New Jersey in NDA approvals in 2010, and California ranked third. Massachusetts is one of three LTS to receive a new BLA approval in 2010; New York, and Pennsylvania also each received one biological approval.

Massachusetts' companies received two medical device pre-market approvals in 2010, second among the LTS, behind California which received six. In the last 13 years, Massachusetts companies have remained relatively consistent on this measure, averaging between two and three pre-market approvals (2.77) per year since 1998. Two other top performers, California and Minnesota, have seen a significant decline in PMAs over that time period. In 2010, however, California saw its first significant increase since 2000, going from one approval in 2009, to six the following year.

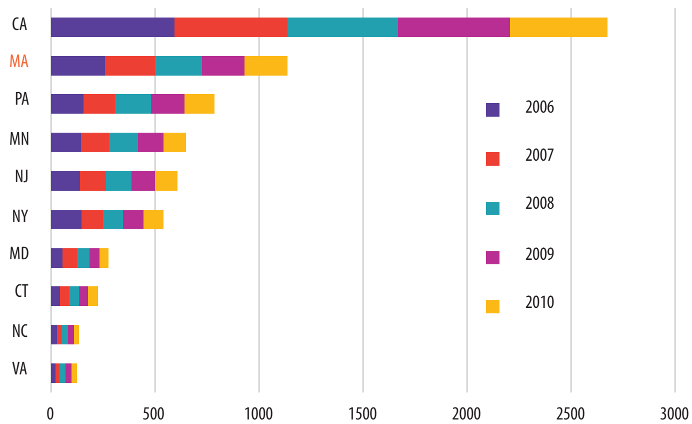
Massachusetts companies were second to California in the number of medical device pre-market notifications in 2010. On a per capita basis, Massachusetts ranked first, followed by Minnesota.

Medical device pre-market approvals (PMAs), LTS 2006-2010



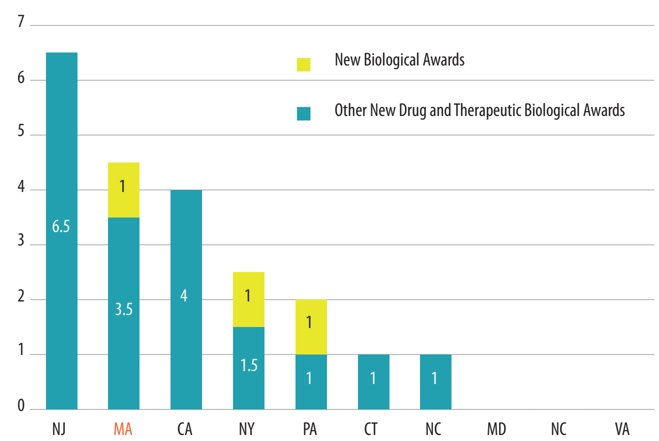
Source: US Food and Drug Administration

Medical device pre-market notifications (releasable 510(k)s), LTS 2006-2010



Source: US Food and Drug Administration

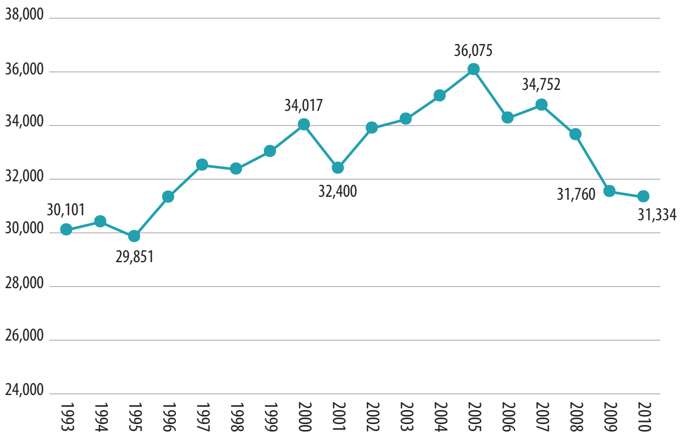
NDA approvals, LTS, 2010



Source: Pharmaceutical Research and Manufacturers of America (PhRMA)

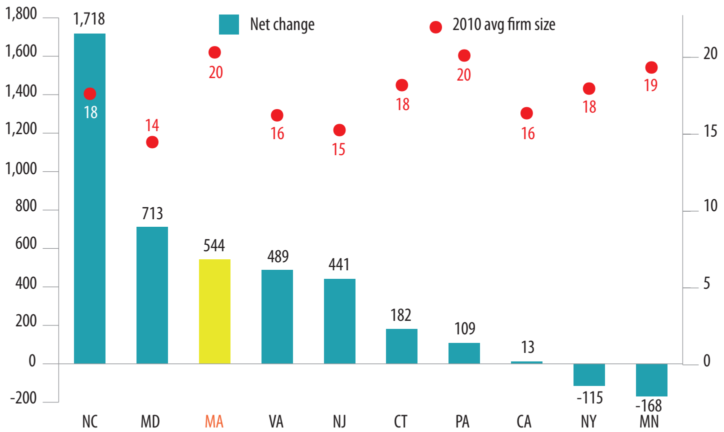
Business Formation

Business establishment openings, Massachusetts, 1993–2010



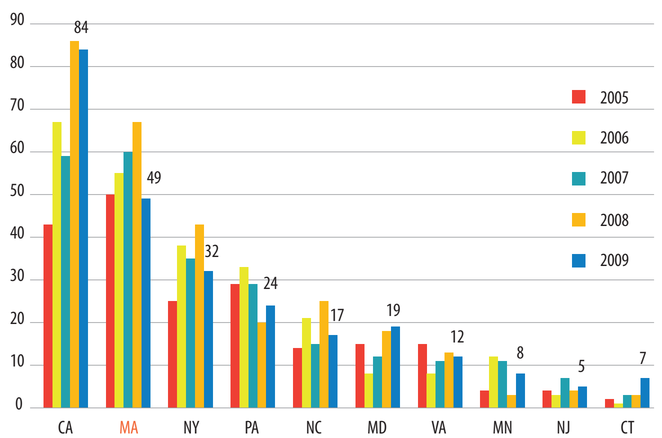
Source: Bureau of Labor Statistics' Business Employment Dynamics

Net change in number of businesses in key industry sectors per million residents in the labor force and average firm size, LTS, 2008-2010



Source: Bureau of Labor Statistics' Quarterly Census of Employment and Wages

Spin-out companies from universities, hospitals, and nonprofit research institutes, LTS, 2005-2009



Source: Association of University Technology Managers

- Business openings in Massachusetts have slowed since 2005, but the percent of individuals becoming entrepreneurs has remained stable through 2010.
- Among key sectors, the largest net increases in establishments in Massachusetts were in Scientific, Technical, and Management Services, followed closely by Software and Communications Services.

Why Is It Significant?

New business formation is a key source of job creation and cluster growth, typically accounting for 30-45% of all new jobs in the U.S. In the Innovation Economy, new business formation is particularly significant in the development and commercialization of new technologies.

The number of 'spinout' companies from universities, teaching hospitals, and nonprofit research institutes (including out-licensing of patents and technology) is a useful indicator for the overall volume of activity dedicated to the translation of research outcomes into commercial applications.

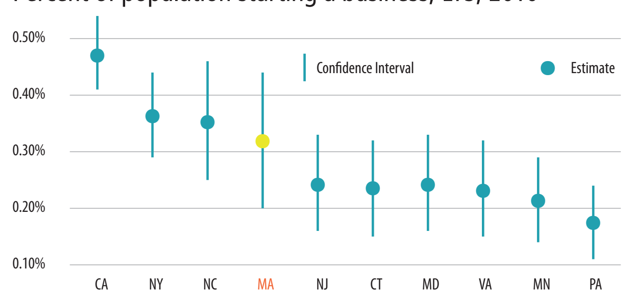
How Does Massachusetts Perform?

In 2010, the number of business establishments opening in Massachusetts fell to its lowest level since 1995, reflecting the slow economic recovery from the recent recession. Four of the LTS, including Massachusetts, had fewer business establishments opening in 2010 than 2009. Massachusetts experienced the smallest loss of the LTS with only 426 fewer openings (-1.34%) in 2010. However, entrepreneurial activity—measured by the Kaufman Foundation as businesses started by people who did not previously own a business—increased in Massachusetts and nationwide in 2010. Entrepreneurial activity increased nationally from 0.28% of the population during 1998-2000 to 0.33% during 2008-2010. For these same periods, this measure increased in Massachusetts from 0.16% of the population during 1998-2000 to 0.29% during 2008-2010. In 2010, entrepreneurial activity in Massachusetts reached an estimated 0.32%.

From 2008 to 2010, the number of business establishments in the key industry sectors increased by 1,766 in Massachusetts. Relative to the size of its labor force, Massachusetts places third among the LTS. The largest increases in Massachusetts were in Scientific, Technical, and Management Services (+ 727, or 7.7%), followed by Software and Communications Services (+ 531, or 5.7%). Seven of the eleven key industry sectors in Massachusetts saw an increase in the number of business establishments from 2008 to 2010.

For the second year in a row, California led Massachusetts in the number of spin-out companies from universities, hospitals, and nonprofit research institutes in 2009. Per capita, Massachusetts maintains a substantial lead in the number of these spin-outs.

Percent of population starting a business, LTS, 2010



Source: The 2010 Kauffman Index of Entrepreneurial Activity

Initial Public Offerings and Mergers and Acquisitions

- After bottoming out in 2008, there were three IPOs of Massachusetts-based companies in 2009 and seven in 2010, which is 4.5% of all IPOs in the U.S. in 2010.
- In 2010, more of Massachusetts' companies were on the acquiring side instead of being acquisition targets.

Why Is It Significant?

IPOs and M&As represent important business strategies with which emerging companies can access capital, expand operations and support business growth. IPOs and M&As also are opportunities for early-stage investors to liquidate their investments. Some M&As enhance research outcomes by bringing together technological expertise and enhancing efficiency. Other M&As can alter incentives to innovate within a business by reducing competition or by allocating innovation to outsourcing via acquisitions of startup companies with proven or promising technologies.

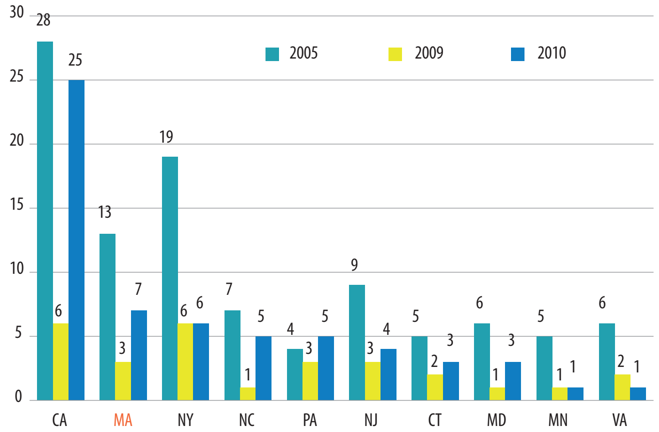
How Does Massachusetts Perform?

The number of IPOs in Massachusetts continued to rise in 2010, having increased slightly in 2009, after plummeting to zero in 2008. There were 72 venture-backed companies that went public in the U.S. in 2010. This is much higher than the 12 venture-backed companies that went public in the U.S. in 2009, a period when many venture firms were deterred by valuation multiples that had not yet returned to pre-recession levels. The number of 2010 venture-backed companies that went public (75) in the U.S. was only 12.7% below 2007 (86). As a result, M&As were lower as a percent of all venture-backed liquidity events.

After bottoming out in 2008 and with only three IPOs in 2009, there were seven IPOs of Massachusetts-based companies in 2010, 4.5% of all IPOs in the U.S. that year. The seven IPOs place Massachusetts second among the LTS after California. Three of the seven IPOs in Massachusetts in 2010 were venture-backed companies (IRWD, AVEO, and AEGR).

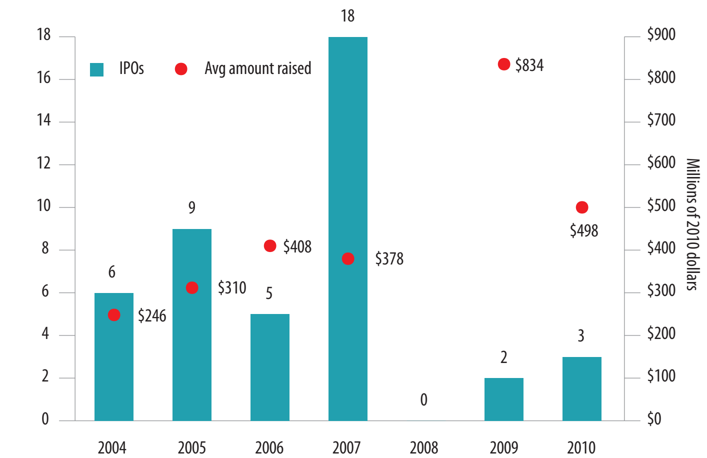
There were 303 acquisitions of Massachusetts-based companies in 2010, 2.0% more than the ten-year average. 2009 was the first time since 2002 when more Massachusetts' companies were acquisition targets than acquiring companies. In 2010, more Massachusetts' companies were acquirors rather than acquisition targets.

Number of initial public offerings, LTS, 2005, 2009, 2010



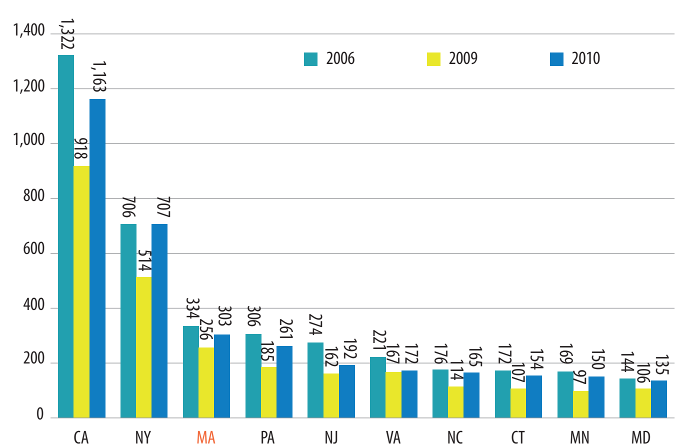
Source: Renaissance Capital, IPO Home

Venture-backed IPOs, Massachusetts, 2004–2010



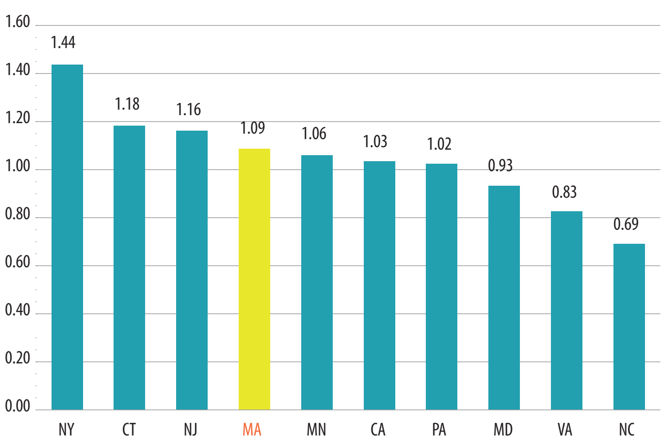
Source: National Venture Capital Association

Mergers and acquisitions by location of acquired company, LTS, 2006, 2009, and 2010



Source: FactSet MergerStat, LLC

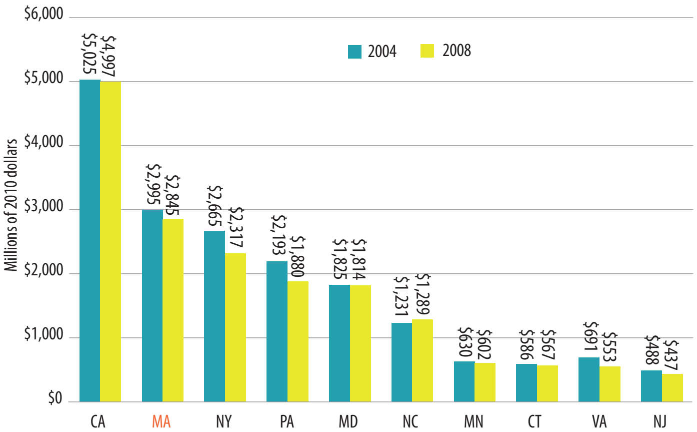
Number of companies bought per company sold, LTS, 2010



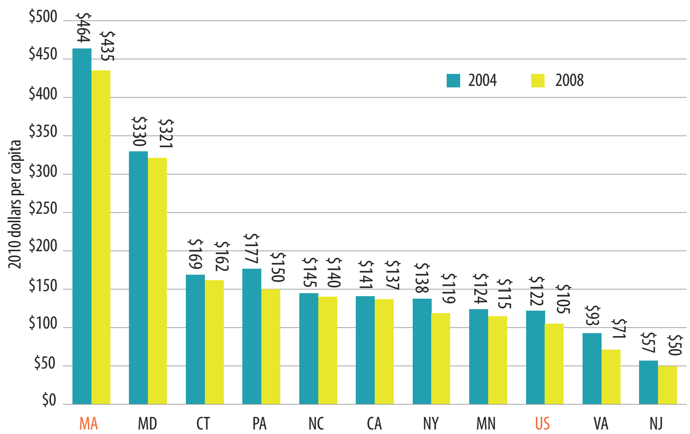
Source: FactSet MergerStat, LLC

Federal Funding for Academic, Nonprofit, and Health R&D

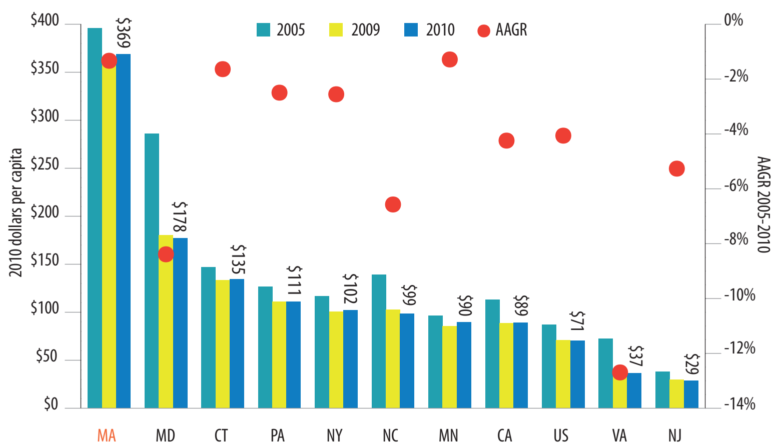
Federal expenditures for academic and nonprofit R&D, LTS, 2004 and 2008



Per capita federal expenditures for academic and nonprofit R&D, LTS, 2004 and 2008



NIH funding per capita and average annual growth rate (AAGR), LTS and US, 2005, 2009 and 2010



Source of all data for this indicator: The National Science Foundation

- Massachusetts' universities and nonprofit research institutes are among the top in the LTS in attracting federal R&D dollars, receiving $2.8 billion in 2008.
- Massachusetts' research institutions continue to attract the largest share of the National Institutes of Health (NIH) funding per capita.

Why Is It Significant?

Universities and other nonprofit research institutes are critical in the Massachusetts Innovation Economy because they advance basic science, create technologies and know-how that can be commercialized by the private sector, and contribute to educating the highly-skilled individuals who constitute one of Massachusetts' greatest economic assets. Funding from the federal government is essential for sustaining academic, nonprofit, and health-related research. For example, awards from the National Institutes of Health (NIH) help fund the Commonwealth's biotechnology, medical device, and health services industries which together comprise the Life Sciences cluster.

How Does Massachusetts Perform?

Whether measured in total dollars or on a per capita basis, universities and nonprofit research institutes in Massachusetts are among the top in the LTS for attracting federal R&D dollars. In 2008, the Massachusetts total of federal R&D dollars was $2.8 billion. In both 2004 and 2008, federal funding for Massachusetts' universities and nonprofit research institutes accounted for 9% of the U.S. total.

The Commonwealth also maintains its leadership position among all LTS in NIH funding. While funding from the NIH increased only 0.05% nationally from 2009 to 2010, the share of funding going to Massachusetts increased 3.3%. In 2010, the Commonwealth was second to California in total dollars received. Massachusetts was first in NIH dollars per capita.

Industry Funding of Academic Research

- The proportion of academic research funded by industry in Massachusetts increased from 6.1% in 2004 to 7.7% in 2009.
- Massachusetts leads the LTS in the amount of industry funding of academic research per capita, with a narrow lead over North Carolina.

Why Is It Significant?

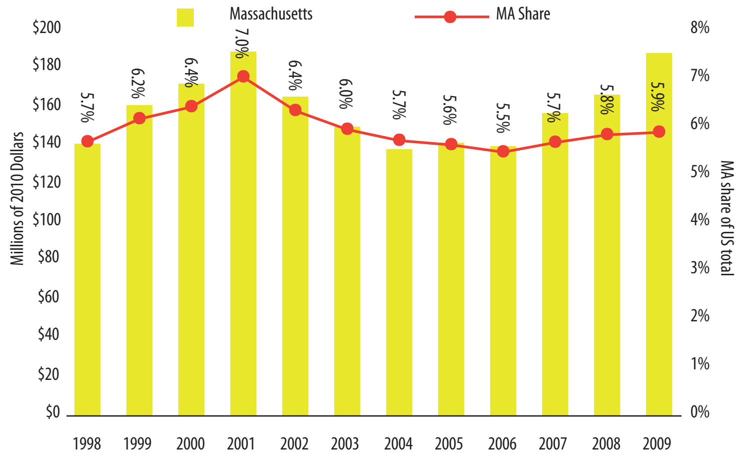
Industry funding of academic research is one measure of industry-university relationships and their relevance to the marketplace. University-industry research partnerships may result in advances in low, medium, and high technology industries. Industry funding aids in advancing basic research that may have commercial applications. Moreover, university research occurring in the context of projects funded by industry helps educate individuals in areas directly relevant to industry needs.

How Does Massachusetts Perform?

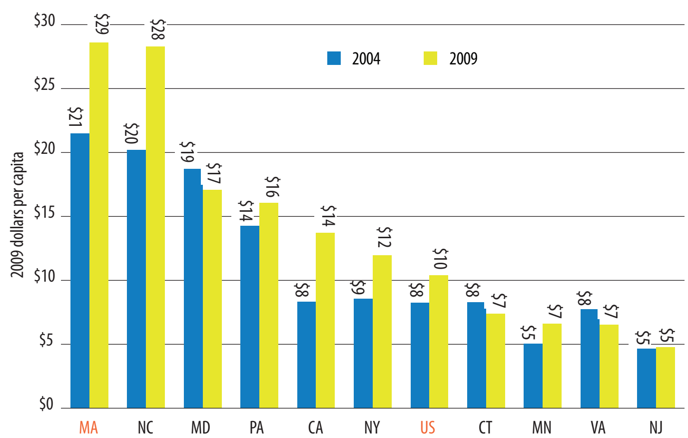
The proportion of academic research in Massachusetts funded by industry increased from 6.1% in 2004 to 7.7% in 2009, the second highest in the LTS after North Carolina. Such funding grew 13.3% between 2008 and 2009, the third annual increase in a row and the most significant increase in five years. The share of total industry funding for academic research in the U.S. going to Massachusetts increased modestly between 2004 and 2009, from 5.6% to 5.9%. In the same period, 14.4% of the increase in academic research funding at Massachusetts colleges and universities came from industry sources. With 12% of academic R&D funded by industry in 2009, North Carolina far exceeds all of the LTS on the proportion of research funded by industry. Duke University and its leadership as a center for clinical trials is a major factor in North Carolina's ranking.

The Commonwealth leads the LTS in the amount of industry funding of academic research per capita. North Carolina follows closely and had faster growth than Massachusetts from 2004 to 2009.

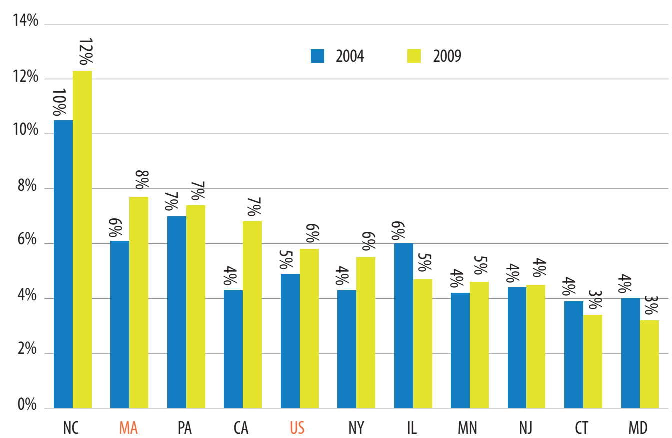
Industry funded academic research, Massachusetts and Massachusetts' share of US total, 1998–2009



Industry funding of academic R&D per capita, LTS and US, 2004 and 2009



Percent of academic R&D funded by industry, LTS and US, 2004 and 2009

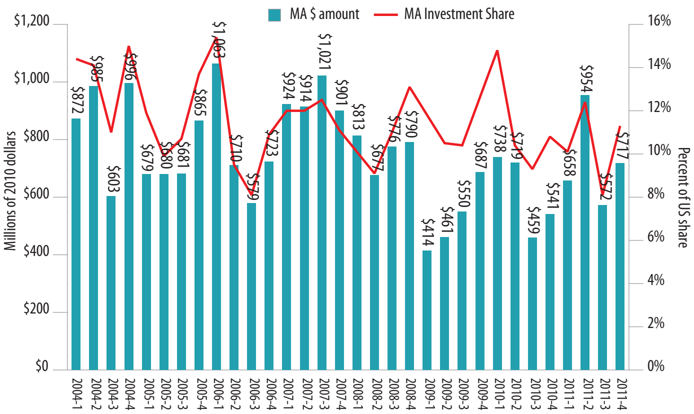


Source of all data for this indicator: The National Science Foundation

CAPITAL

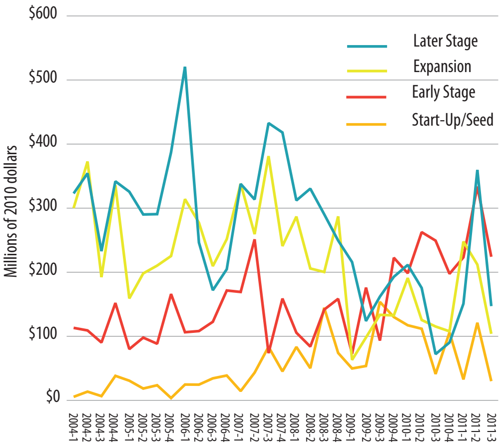
Venture Capital

Venture capital (VC) investment in Massachusetts and as a share of total VC investment in the US, 2004 Q1–2011 Q4



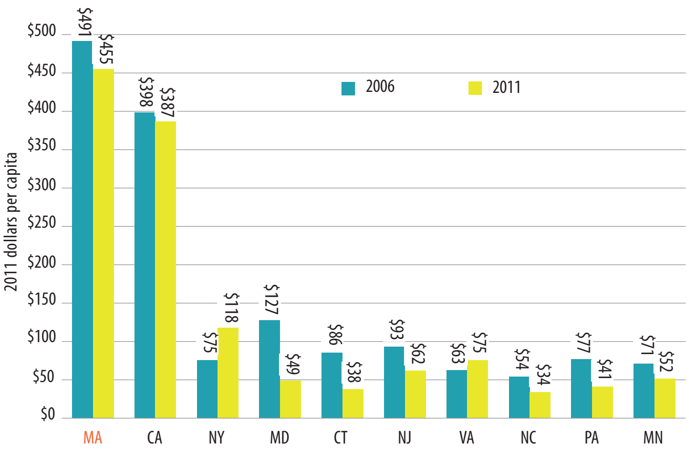
Source: PricewaterhouseCoopers MoneyTree Report

MA Venture capital investment by stage of financing, 2004 Q1–2011 Q3



Source: Thomson Reuters and National Venture Capital Association

Venture capital investment per capita, LTS, 2006 and 2011



Source: PricewaterhouseCoopers MoneyTree Report

- Based on the first three quarters of 2011, venture capital funds going to startup, seed, and early stage businesses in Massachusetts were tracking closely to the height of the 2000 tech bubble, with $0.94 billion already invested.
- Despite a significant decrease in the absolute amount of venture capital dollars invested in the state since 2007 ($2.9 billion in 2011, down from $3.8 billion in 2007), Massachusetts still leads the LTS in VC investments per capita in 2011.
- Through the first three quarters of 2011, the Biotechnology sector received more than double the venture funding of any other sector in Massachusetts.

Why Is It Significant?

Venture capital (VC) firms are an important source of funds for the creation and development of innovative new companies. VC firms also typically provide valuable guidance on strategy as well as oversight and governance. Trends in venture investment can indicate emerging growth opportunities in the Innovation Economy. Private investment capital derived from sources such as individual 'angel' investors is also important for seed and early stage companies, but not included in these data.

How Does Massachusetts Perform?

The amount of capital allocated to venture capital firms began to rise in 2011. The amount of venture dollars invested in Massachusetts companies in Q2 2011 reached its highest quarterly point since Q3 2007, only 2.4% below the 2007 peak. The amount invested by VC firms in Massachusetts companies grew by 18.1% from 2010 to 2011 and 26.2% nationally. Massachusetts companies received 10.5% of the $27.7 billion invested across the country in 2011 and also accounted for 10.4% of the number of deals nationally. Massachusetts still led the LTS in VC investment per capita, notwithstanding a decline in total venture dollars invested into companies from 2006 to 2011.

From Q1 2009 to Q3 2011, VC funding going to startup, seed, and early stage businesses in Massachusetts was the highest since the height of the 2000 tech bubble, with $3.2 billion invested; the majority (55%) of this amount was invested in biotechnology firms.

Companies in the Biotechnology, Software, Medical Devices, and Industrial/Energy sectors in Massachusetts received the most venture dollars in Q1 2011 across all stages of financing. The Biotechnology sector received more than double the funding of any other sector in Massachusetts.

Education Level of the Workforce

- Massachusetts continues to rank first among the LTS and the U.S. in the percent of the working age population with a bachelor's degree or higher.
- From 2009 to 2010, the employment rate of the working age population in Massachusetts increased for residents with a bachelor's degree or higher while it remained stable or continued to fall for residents with less education.

Why Is It Significant?

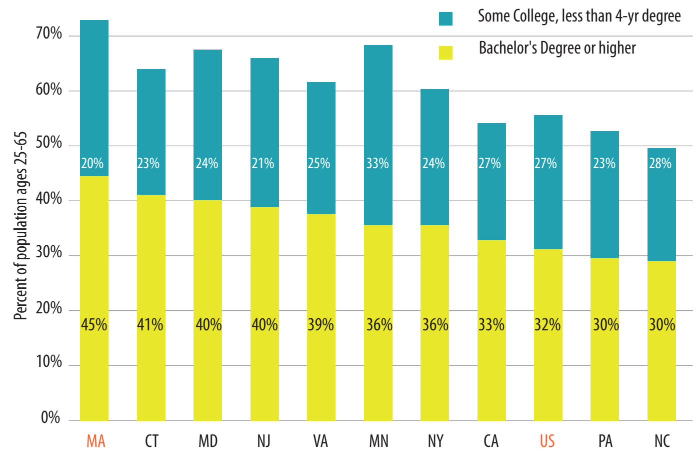
A well-educated workforce constitutes an essential component of a region's capacity to generate and support innovation-driven economic growth. Challenges to maintaining a suitably trained labor force in Massachusetts include the need to increase skill levels and technical sophistication of workers, as well as the aging of the baby-boomer generation of employees.

How Does Massachusetts Perform?

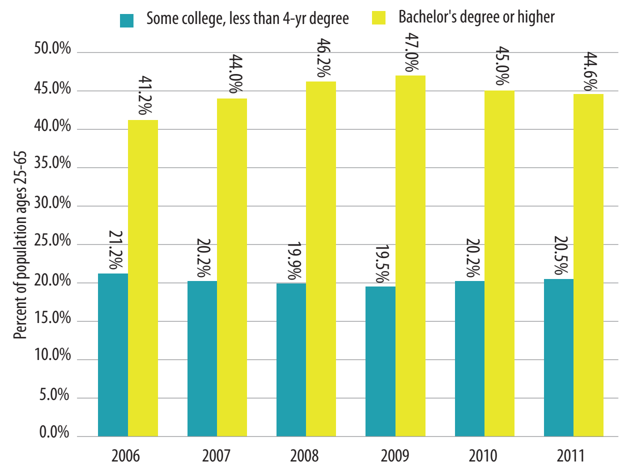
Massachusetts continues to rank first in the U.S. in the percent of its working age population with a four-year college degree or higher. In 2011, 44.6% of the working age population in Massachusetts had a bachelor's degree or higher, compared to 31.7% nationally. Massachusetts maintains this leadership position despite a small decline (-0.4%) in 2011 from 2010.

Employment rates during current economic conditions reinforce the importance of a college education in the Massachusetts' labor market. From 2009 to 2010, full-time employment continued to fall for individuals with only a high school education. In contrast, employment held steady for the working age population with some college education and increased to above 2005 levels (77.0%) for those with a bachelor's degree or higher. In the U.S. as a whole, the employment rate of the working age population continued to fall across the educational spectrum, but fell faster at lower educational attainment levels.

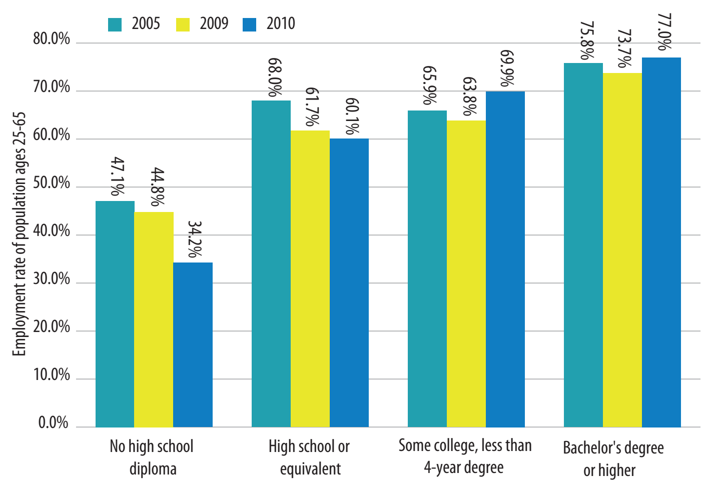
Educational attainment of working age population, LTS and US, 2009-2011 average



College attainment of the working age population, Massachusetts, 2006-2010 three-year rolling average



Full-time employment rate by education, Massachusetts, 2005, 2009, 2010



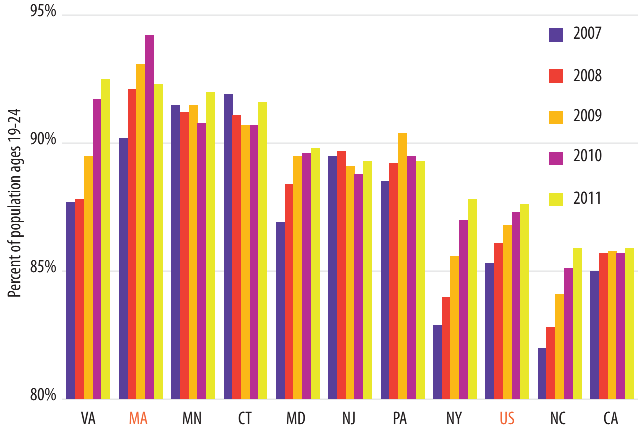
Source of all data for this indicator: US Census Bureau, Current Population Survey

INDICATOR 21

TALENT

K–16 Education

High school attainment of persons ages 19-24, LTS, three year rolling averages, 2007-2011



Source: US Census Bureau, Current Population Survey

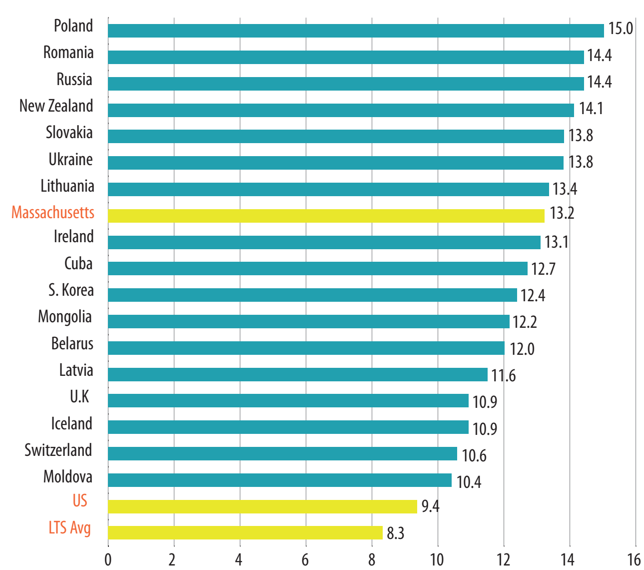
INTERNATIONAL

Top 15 nations participating in the 8th grade TIMSS science evaluation, with Massachusetts, 2007

Source: International Association for the Evaluation of Educational Achievement

INTERNATIONAL

Post-secondary degrees conferred per thousand residents, all levels, international, 2009



Source: United Nations Educational, Scientific and Cultural Organization (UNESCO) and the National Center for Education Statistics

- Only 8% of young adults in Massachusetts lacked a high school credential in 2011, down from 11% in 2006.
- In science and mathematics, Massachusetts students outperform their U.S. peers and are highly competitive internationally.

Why Is It Significant?

Education plays a very important role in preparing Massachusetts' residents to succeed in their evolving job requirements and career trajectories. A strong education system also helps attract and retain workers who want excellent educational opportunities and skills for themselves and their children. Economic growth in Massachusetts is strongly dependent upon improving the skill mix of the population, especially because of relatively slow population growth. Some of the key metrics for talent development are mathematics ability, high school diploma attainment, and college degrees conferred.

How Does Massachusetts Perform?

Massachusetts has the second highest high school attainment rate among the LTS as measured by the percent of the population ages 19-24 with at least a high school diploma or GED. The progress achieved by the K-12 education system is evident in rising educational attainment among the youngest adults. The percent of the Massachusetts' population aged 19-24 who have not yet completed high school dropped to 7.7% in 2011 from 11.0% in 2006. Over the last five years, Massachusetts' improvement on this measure is consistent with that of the nation as a whole.

In science and in mathematics, Massachusetts' students outperform their U.S. peers and are highly competitive internationally. Massachusetts' eighth-grade students taking the Trends in International Math and Science Study (TIMSS) science assessment in 2007[1] ranked third behind Singapore and Taiwan. The state ranked fourth internationally in mathematics. In higher education, the Commonwealth ranked eighth globally in 2009 in degrees conferred per capita after Poland, Romania, Russia, New Zealand, Slovakia, Ukraine, and Lithuania. The U.S., in comparison, ranked 19th.

[1] The TIMSS is done every 5 years. 2007 was the last time the study was performed; it will be done again in 2012.

Public Investment in K–16 Education

- During the last five years, Massachusetts increased per pupil support for K-12 education.
- Meanwhile, per pupil support for public higher education in Massachusetts fell to 7% below the national average in 2010.

Why Is It Significant?

Investments in elementary, middle and high schools are important for preparing a broadly educated and innovation-capable workforce. Investments in public, postsecondary education are critical to increase the ability of public academic institutions to prepare students for skilled and well-paying employment. In addition, well-regarded, public higher education programs enhance Massachusetts' distinctive ability to attract students from around the globe, some of whom choose to work in the Commonwealth after graduation.

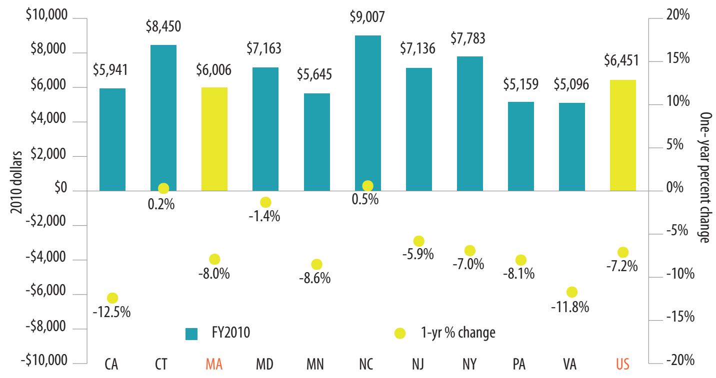
How Does Massachusetts Perform?

From 2002 to 2009, per pupil support for K-12 education in Massachusetts rose at an average annual rate of 2.7%. From 2008 to 2009, it rose 5.3%, maintaining the state's fourth place rank among the LTS.

Massachusetts' appropriations for higher education have declined significantly since the late 1980s, whether viewed per student, per capita, or relative to the size of the Massachusetts economy. In 2003, Massachusetts' appropriations per student were 23% above the U.S. average; in contrast, in 2010 they were 7% below the national average. From 2009 to 2010, per pupil support for higher education in Massachusetts declined by 8%. Moreover, in 2010, while appropriations fell 2.2%, enrollments rose 6.3%, leading to an 8.0% decline in per pupil appropriations.

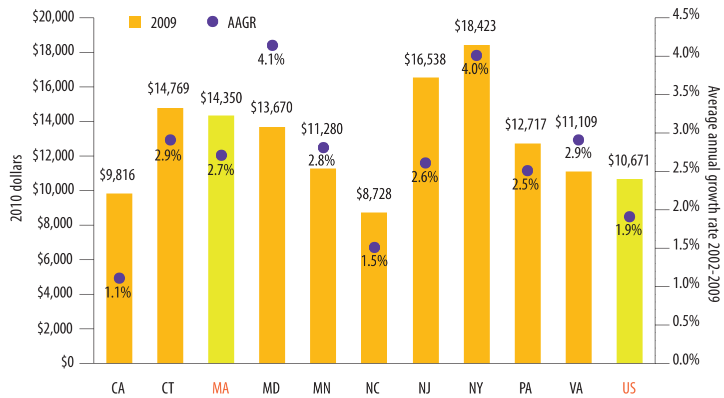
In 2008, Massachusetts ranked 16th compared to high-income nations* in per pupil public investment in education (inclusive of all levels) relative to per capita GDP. Massachusetts held steady on this measure from 2004 to 2008. The U.S. ranks 19th on this measure, just behind Poland.

State higher education appropriations per full-time equivalent student, LTS, 2010



Source: State Higher Education Executive Office

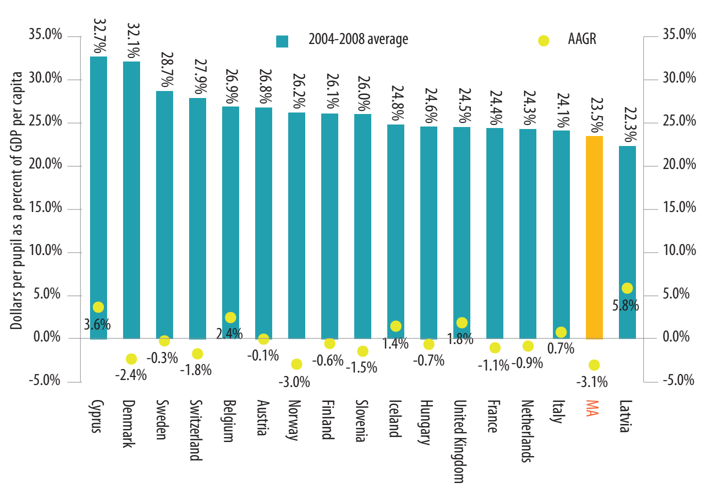
Per pupil spending of public elementary/secondary school systems, LTS, 2009



Source: US Census Bureau

INTERNATIONAL

Per pupil investment in public education, all levels, international, 2004-2008



Source: United Nations Educational, Scientific and Cultural Organization (UNESCO), Bureau of Economic Analysis, the National Center for Education Statistics, State Higher Education Executive Officers (SHEEO) and the Census Bureau

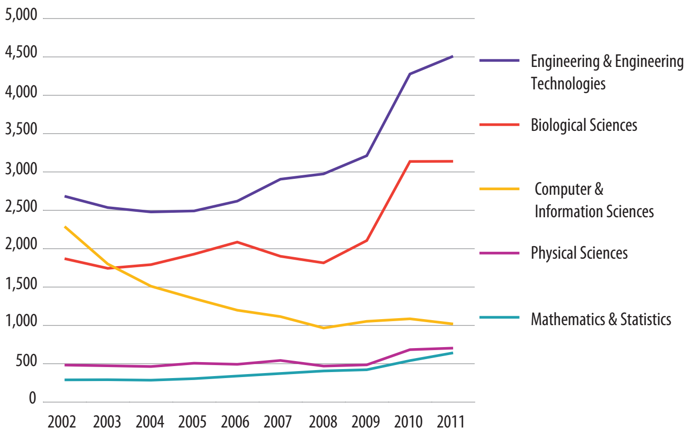
*In order to make comparisons based on GDP per capita, the nations selected were all high income as defined by the World Bank. See appendix for more information.

INDICATOR 23

TALENT

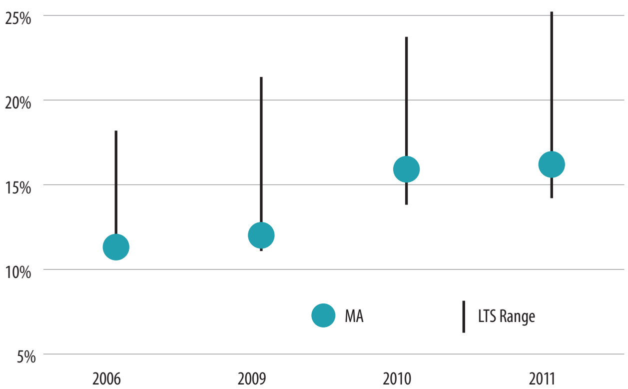
Science, Technology, Engineering, and Math Career Choices and Degrees

Intended major of high school seniors, Massachusetts, 2002-2011



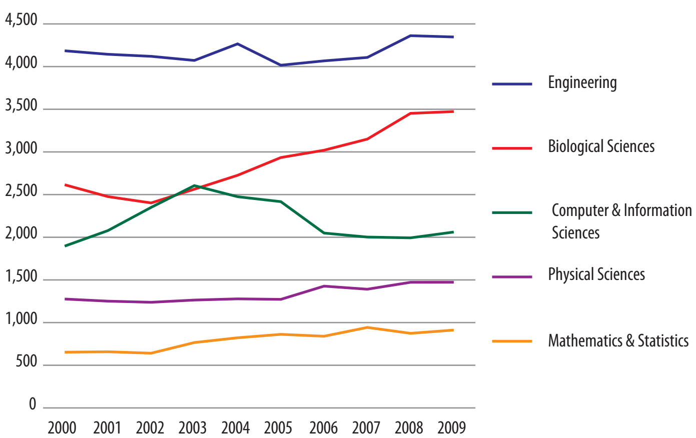
Source: The College Board

Percent of high schools seniors taking the SATs intending to major in a STEM field , MA and LTS range, 2006, 2009–2011



Source: The College Board

Degrees granted in STEM fields, Massachusetts, 2000-2009



Source: Integrated Postsecondary Education Data Systems

- In 2011, interest among Massachusetts high school students in science, technology, engineering, and math (STEM) fields reached its highest level in at least ten years
- Interest among high school students in Massachusetts in STEM fields, however, is still 8.7% below the national average.

Why Is It Significant?

Science, technology, engineering, and math (STEM) education provides the skills and know-how that can help increase business productivity and form the basis for higher-paying jobs. Clusters of firms with concentrations of employees with these skills can drive productivity growth across sectors and contribute to the creation of new technologies and companies. Massachusetts' comparatively high earnings and quality of life have been achieved, in large part, through innovations and individuals trained in these fields.

Demand for professionals in STEM fields is particularly high in Massachusetts.

Business leaders in the Commonwealth are highlighting the "STEM pipeline issue" because the number of students majoring in these critical fields is not sufficient to fill the vacancies expected as baby boomers retire during the coming decade.

How Does Massachusetts Perform?

In 2010, the number of students in Massachusetts' high schools showing interest in majoring in a STEM field reached the highest level in at least ten years. Interest in mathematics grew the fastest, doubling since 2002. In terms of total students, interest in engineering and engineering technologies grew the most. Interest in computer and information science declined in 2011, following a rebound in 2009 and 2010 from a seven-year decline (from 2001 to 2008).

From 2006 to 2011, overall interest in STEM fields increased among all of the LTS and the U.S., with Massachusetts (43.1%) leading in the percentage increase. This moved Massachusetts' rank from last among the LTS in 2005 to sixth out of ten in 2010. However, Massachusetts is still 8% below the national average on this measure.

Bachelor and graduate degrees granted in STEM fields increased steadily in Massachusetts from 10,625 in 2000 to 12,266 in 2009. During the five-year period from 2004 to 2009, degrees granted in biological sciences grew the most (27.4%), adding 747 degrees (3,473 total in 2009). Computer and Information Science was the only STEM field in which degrees granted declined.

Talent Flow and Attraction

- After six years of population losses from 2002 through 2007, Massachusetts turned the tide and recorded population increases (domestic migration gains) in 2008 and 2009.
- While overall geographic mobility declined in 2009, Massachusetts still experienced positive net migration for the second straight year.
- Massachusetts ranks first among the LTS in the combined flow of college educated adults migrating to the state from other states and abroad.

Why Is It Significant?

Migration patterns are a key indicator of a region's attractiveness. Regions that are hubs of innovation have high concentrations of educated, high-skilled workers and dynamic labor markets refreshed by inflows of talent. In-migration of well-educated and highly skilled individuals fuels innovative industries by bringing in diverse and high-demand skill sets. While a positive net talent flow is important, Massachusetts benefits from talent flows in both directions, connecting Massachusetts institutions and businesses to other regions.

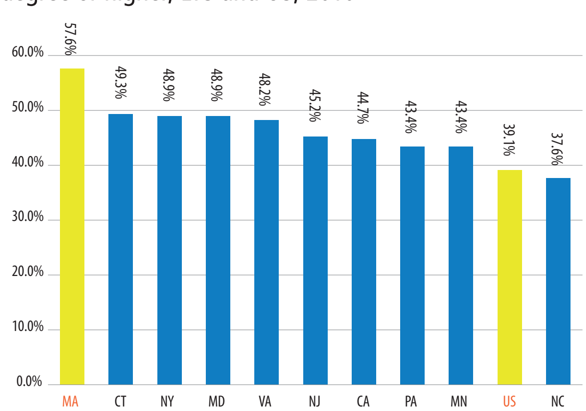
How Does Massachusetts Perform?

The economic and housing crises have dampened mobility nationally, with state-to-state migration down 5% in the US in 2009. International immigration declined 11% that year. The net impact on Massachusetts has been a 7% decline in new residents moving in. However, far fewer people left Massachusetts, thus net migration in the state was positive. After six years of population losses from 2002 through 2007, Massachusetts turned the tide and recorded domestic migration gains in 2008 and 2009. As a share of population, net migration had the greatest impact in North Carolina and Massachusetts in 2008 and 2009.

Massachusetts leads all other states in the percent of in-migrants with a bachelor's degree or higher at 57% in 2010, with Connecticut the closest LTS with 49%. College attainment among international immigrants to Massachusetts rose over the last six years from 42% to 56%.

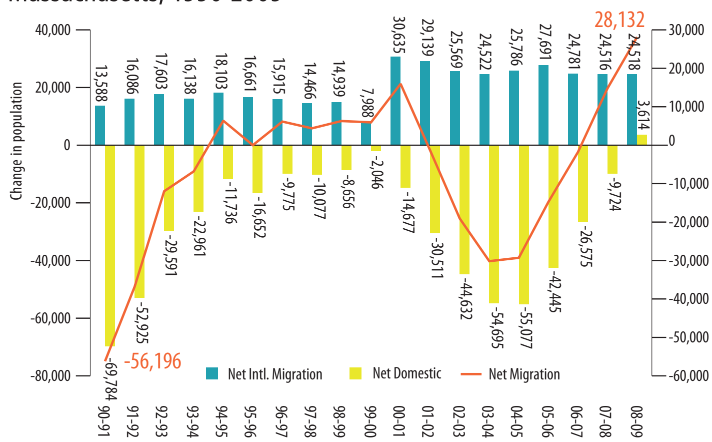
State-to-state and international relocations by college-educated adults declined in six of the ten LTS from 2009 to 2010, with Pennsylvania and, to a lesser extent, Massachusetts, New York and Minnesota bucking the downward trend. Massachusetts gained more college-educated workers per capita through immigration than all other LTS in 2010.

Percent of migrants to the LTS with a bachelor's degree or higher, LTS and US, 2010



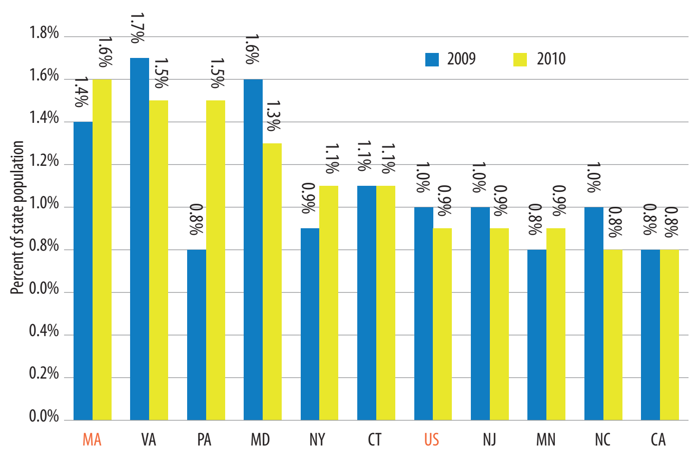
Source: US Census Bureau, American Community Survey

Net international and domestic migration, Massachusetts, 1990-2009



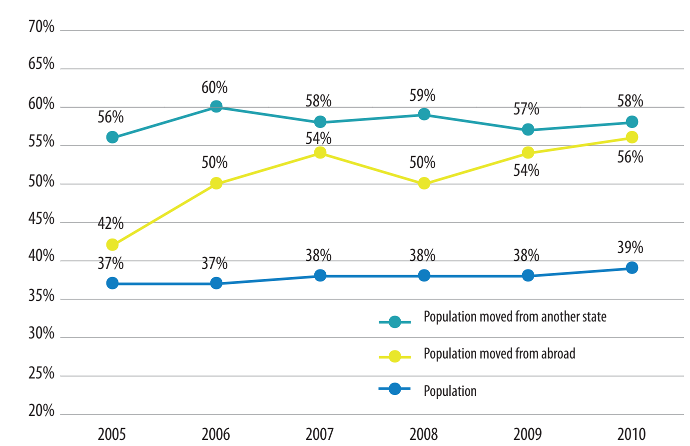
Source: US Census Bureau

Relocations by college educated adults to the LTS from out of state or abroad, 2009 and 2010



Source: US Census Bureau, Current Population Survey

Percent of population with a bachelor's degree or more, Massachusetts, 2005–2010



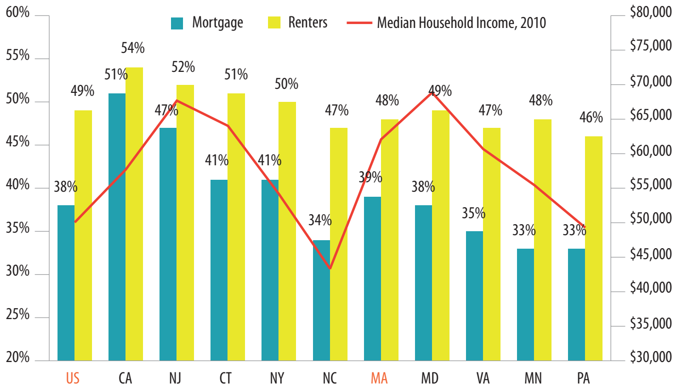
Source: US Census Bureau

INDICATOR 25

TALENT

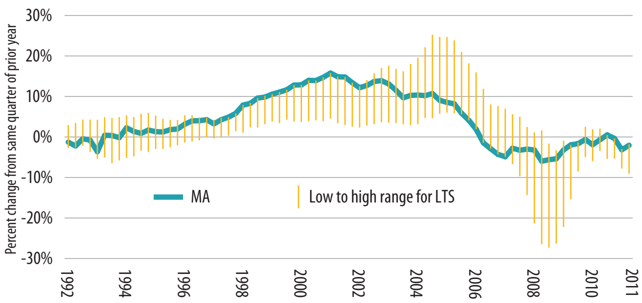
Housing Affordability

Households spending 30 percent or more of income on housing costs, LTS and US, 2010



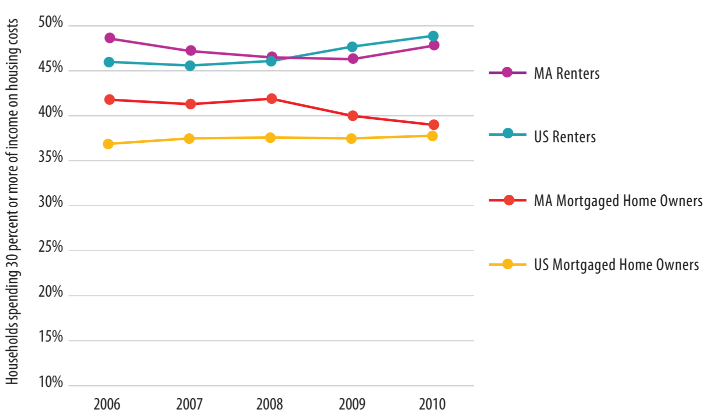
Source: US Census Bureau, American Community Survey

Housing price index, Massachusetts and low to high range for LTS, 1992 - 2011



Source: Federal Housing Finance Agency

Housing affordability trends for renters and home owners with mortgages, Massachusetts and US, 2006-2010



Source: US Census Bureau, American Community Survey

- The number of renters and homeowners with mortgages spending more than 30% of income on housing costs in Massachusetts declined slightly in 2010.
- California and Massachusetts continue to have the highest median home prices of the LTS, both of which were above $300,000 in Q2 2010.

Why Is It Significant?

Assessments of 'quality of life', of which housing affordability is a major component, influence Massachusetts' ability to attract and retain talented people. Also, a lack of affordable housing for essential service providers and entry-level workers can deter individuals from moving to the area, thus slowing business' ability to fill open positions and fuel expansion in the region. Spending 30% or more of income on housing costs is a common threshold for measuring housing affordability.

How does Massachusetts Perform?

Massachusetts, like the rest of the nation, has experienced housing price deflation over the last five years, reversing a trend, beginning in 2000, in which housing cost increases drastically outpaced income growth. In 2011, median prices in Massachusetts are hovering around $300,000 after peaking at over $350,000 in 2005. While this represents more than a 15% decline, median home prices decreased nationally by more than 23% from over $223,000 in 2006 to around $180,000 in 2010. [The data series used for this analysis was produced in connection with an ad hoc publication. While the Federal Housing Finance Agency (FHFA) may produce such a series in the future, there are no specific plans at the moment.]

Coupled with housing price declines, more homeowners with mortgages in Massachusetts have housing costs that are considered affordable than in 2009. The number of homeowners with mortgages requiring more than 30% of income declined slightly for a second year in a row 2009 to 2010 from 40% to 39%. This contrasts with the rest of the nation as national mortgage affordability has remained static for four years beginning in 2007. For renters, conditions across the nation also failed to improve for the third continuous year as the percent of renters spending more than 30% of their income on housing increased from 48% in 2009 to 49% in 2010. This measure increased in Massachusetts from 46% in 2009 to 48% in 2010.

California continues to maintain its status as the least affordable of the LTS, with the highest percent of both renters and mortgaged homeowners spending more than 30% of monthly income on housing (54% and 51% respectively). California also has the highest median house price as of Q2 2010 at just over $330,000.

APPENDIX A: DATA SOURCES FOR INDICATORS AND SELECTION OF LTS

Data Availability

Indicators are calculated with data from proprietary and other existing secondary sources. In most cases data from these sources were organized and processed for use in the **Index**. Since these data are derived from a wide range of sources, content of the data sources and time frames are not identical and cannot be compared without adjustments. This appendix provides information on the data sources for each indicator.

Price Adjustment

The **2011 Index** uses inflation-adjusted figures for most indicators. Dollar figures represented in this report, when indicated, are in 'chained' (adjusted for inflation) 2010 dollars. Price adjustments are according to the Consumer Price Index for all Urban Consumers (CPI-U), US City Average, All Items.

Bureau of Labor Statistics, US Dept. of Labor. http://data.bls.gov/cgi-bin/surveymost

I. Selection of Leading Technology States (LTS) for Benchmarking Massachusetts Performance

The **Index** benchmarks Massachusetts performance against other leading states and nations to provide the basis for comparison. The Leading Technology States (LTS) list, which was updated in 2011, includes: California, Connecticut, Maryland, Minnesota, New Jersey, New York, North Carolina, Pennsylvania, and Virginia. The LTS are chosen by the number of select key industry sectors with a high concentration of employment, the percent of employment in these sectors, and the size of each states' economy. The sectors used for this purpose are Bio-pharma & Medical Devices, Computer & Communication Hardware, Defense Manufacturing & Instrumentation, Financial Services, Postsecondary Education, Scientific, Technical, & Management Services, and Software & Communications Services. The sector employment concentration for each state measures sector employment as a percent of total employment to the same measure for the US as a whole. This ratio, called the 'location quotient' (LQ), is above average if greater than one. The LTS are the ten states with the greatest number of sectors with a location quotient greater than 1.1, ranked by the percent of jobs in the key sectors, excluding states with fewer than a half million jobs in the key sectors. The size threshold excludes states such as New Hampshire, Rhode Island, and Utah. This methodology yields a roster of LTS that is comparable to Massachusetts and has a similar composition of industry sectors.

2011 Industry Sector Employment Concentrations

2011 Sector Employment (LQ)	MA	CT	CA	PA	MN	NC	NJ	MD	VA	NY
Bio-pharma & Medical Devices	2.23	1.50	1.40	1.39	1.58	1.39	2.37	1.06	0.54	0.89
Computer & Com Hdw	1.79	1.12	2.14	0.97	1.41	1.42	0.63	0.54	0.42	0.86
Defense Mfg	1.33	3.08	1.29	0.73	0.65	0.55	0.52	0.54	0.25	0.51
Financial Services	1.38	1.84	0.81	1.17	1.28	0.92	1.23	0.79	0.64	1.38
Postsecondary Education	1.33	1.15	1.04	1.06	0.86	1.10	0.82	1.17	0.97	1.20
Scientific, Tech, & Mgt Serv	1.20	0.69	1.23	0.82	0.70	0.87	0.96	1.81	1.87	0.89
Software & Com Serv	1.51	0.99	1.11	0.85	1.01	0.82	1.25	1.44	2.09	0.98
Advanced Materials	0.86	0.83	0.60	1.40	0.91	1.48	1.00	0.39	0.82	0.58
Business Services*	1.03	0.92	0.95	1.14	1.18	0.92	1.12	0.88	1.29	1.17
Diversified Industrial Mfg.	1.18	1.74	0.83	1.25	1.49	0.90	0.70	0.34	0.63	0.79
Healthcare Delivery	1.17	0.99	0.85	1.09	1.00	1.05	0.97	0.95	0.81	1.08
Count of Sectors with LQ>1.1	9	6	5	5	5	4	4	3	3	3
Percent of Jobs in Key Sectors	38.4%	35.9%	29.4%	32.5%	32.2%	30.6%	31.8%	29.7%	30.4%	32.1%

Cells are shaded to show industry sector concentrations more than 10% above the US average.

Source: BLS QCEW.

II. Notes on selection of comparison nations

For all the indicators that include international comparisons, countries displayed on the graph are the top performers for that measure. In some cases, the countries are selected high income nations as defined by the World Bank due to the small denominator effect. Categories of data not reported by excluded countries vary from category to category.

III. Notes on international data sources

For countries where the school year or the fiscal year spans two calendar years, the year is cited according to the later year. For example, 2004/05 is presented as 2005. All international population estimates are obtained from the World Bank. Total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship—except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin. The numbers shown are midyear estimates. The World Bank estimates population from various sources including census reports, the United Nations Population Division's World Population Prospects, national statistical offices, household surveys conducted by national agencies, and Macro International. Statistics on China obtained from the United Nations Educational, Scientific, and Cultural Organization (UNESCO) do not include the two Special Administrative Regions of Hong Kong and Macao. All economic data, such as GDP, GNI, and exchange rates, used by UNESCO in the **Index**, are provided by the World Bank and are revised on a biannual basis.

IV. Notes on overview charts

The overview charts are created with the calculations used for the corresponding indicators. The definitions for each of the measures are also the same as defined in the indicators, except for mortgage and rent affordability, which are based on the number of renters and mortgage holders who do not have to spend 30% or more of income on housing as opposed to those who do. The measures are per capita comparisons unless otherwise indicated or unless based on an average or median. The arrows represent the direction of change in Massachusetts since the previous year. The charts are not indexed to the United States average or comparing to the LTS.

V. Notes on Data Sources for Individual Indicators

1. Industry Sector Employment and Wages

Data on sector wages are from the Bureau of Labor Statistics' Quarterly Census of Employment and Wages. This survey derives employment and wage data from workers covered by state unemployment insurance laws and federal workers covered by the Unemployment Compensation for Federal Employees program. Wage data denote total compensation paid during the four calendar quarters regardless of when the services were performed. Wage data include pay for vacation and other paid leave, bonuses, stock options, tips, the cash value of meals and lodging, and contributions to deferred compensation plans. Definitions for each key industry sector are in Appendix B. http://www.bls.gov/cew/

2. Occupations and Wages

The US Bureau of Labor Statistics' Occupational Employment Statistics (OES) program estimates the number of people employed in certain occupations and wages paid to them. The OES data include all full-time and part-time wage and salary workers in non-farm industries. Self-employed persons are not included in the estimates. The OES uses the Standard Occupational Classification (SOC) system to classify workers. MTC aggregated the 22 major occupational categories of the OES into 10 occupational categories for analysis. http://www.bls.gov/oes/home.htm

The occupational categories in the **Index** are:

- Arts & Media: Arts, design, entertainment, sports, and media occupations.
- Construction & Maintenance: Construction and extraction occupations; Installation, maintenance, and repair occupations.
- Education: Education, training, and library occupations.
- Healthcare: Healthcare practitioner and technical occupations; Healthcare support occupations.
- Computer and Mathematical: Computer and mathematical occupations.
- Science, Architecture, and Engineering Occupations: Architectural and engineering occupations; life, physical, and social science occupations.
- Business, Financial, and Legal Occupations: Management occupations; Business and financial operations occupations; and Legal occupations.
- Production: Production occupations.
- Sales & Office: Sales and related occupations; Office and administrative support occupations.
- Community and Social Service: Community and social service occupations.
- Other Services: Protective service occupations; Food preparation and serving related occupations; Building and grounds cleaning and maintenance occupations; Personal care and service occupations; Transportation and material moving occupations; Farming, fishing, and forestry occupations.

3. Median Household Income

Median household income

Median household income data are from the US Census Bureau, American Community Survey. For the **2011 Index**, data are one year estimates. http://www.census.gov

Wages and salaries paid

Data are from the Bureau of Economic Analysis series "State Personal Income, wage and salary disbursements by place of work for Massachusetts." http://www.bea.gov/regional/

4. Productivity

Manufacturing productivity in key industry sectors

For this measure, productivity is defined as manufacturing value added per manufacturing employee. Industry definitions used are the manufacturing components of the key industry sectors (only NAICS codes beginning with the number 3). For information on the calculation of value added, see Indicator 5 below. Data are from the Census Bureau's Annual Survey of Manufactures. http://www.census.gov/manufacturing/asm/index.html

International labor productivity

Labor productivity for the overall economy is defined by the **Index** as gross domestic product (GDP) per employee. Data on GDP are from the World Bank. http://data.worldbank.org. Data on total employment are from the International Labour Organization (ILO). http://laborsta.ilo.org/

5. Industry Output and Manufacturing Value Added

Industry output

Industry output data are obtained from the Moody's Economy.com Data Buffet. Moody's estimates are based on industry output data for 2 and 3 digit NAICS produced by the Bureau of Economic Analysis (BEA). The BEA's calculations are value added estimates. The term "value added" defines output as final sales in a given sector less the value of intermediate goods and services purchased to facilitate their production. The main components of value added include the returns to labor (as measured by compensation of employees), returns to capital (as measured by gross operating surplus), and the returns to government (as measured by taxes on productions and imports less subsidies). The fraction of the 2 or 3 digit NAICS data are allocated by Moody's to 4 digit NAICS industries using the ratios of total wages paid between sectors and their parent industries http://www.economy.com.

Manufacturing value added
Data are from the Census Bureau's Annual Survey of Manufactures. The Census Bureau defines value added as follows: "This measure of manufacturing activity is derived by subtracting the cost of materials, supplies, containers, fuel, purchased electricity, and contract work from the value of shipments (products manufactured plus receipts for services rendered). The result of this calculation is adjusted by the addition of value added by merchandising operations (i.e., the difference between the sales value and the cost of merchandise sold without further manufacture, processing, or assembly) plus the net change in finished goods and work-in-process between the beginning- and end-of-year inventories. For those industries where value of production is collected instead of value of shipments, value added is adjusted only for the change in work-in-process inventories between the beginning and end of year. For those industries where value of work done is collected, the value added does not include an adjustment for the change in finished goods or work-in-process inventories. 'Value added' avoids the duplication in the figure for value of shipments that results from the use of products of some establishments as materials by others." http://www.census.gov/manufacturing/asm/index.html

6. Manufacturing Exports

Manufacturing exports data are from the World Institute for Strategic Economic Research (WISER) at Holyoke Community College's Kittredge Business and Technology Center. http://www.wisertrade.org/

The export categories match up with the sectors as follows:

- Computer and Electronic Products: Bio-Pharma & Medical Devices, Computer and Communications Hardware, and Defense Manufacturing and Instrumentation.
- Chemicals: Advanced Materials and Bio-Pharma & Medical Devices.
- Electrical Equipment, Appliances, and Components: Computer and Communications Hardware and Diversified Industrial Manufacturing.
- Fabricated Metal Products: Defense Manufacturing and Instrumentation and Diversified Industrial Manufacturing.
- Machinery, except electrical: Defense Manufacturing and Instrumentation and Diversified Industrial Manufacturing.
- Miscellaneous Manufactured Commodities: Diversified Industrial Manufacturing
- Plastics and Rubber Products: Advanced Materials
- Primary Metal Manufacturing: Advanced Materials
- Transportation: Defense Manufacturing and Instrumentation.

7. Research and Development Performed

Research and development (R&D) performed
Data are from the National Science Foundation's table of all R&D funds by state, performing sector, and source of funds. Data used are the totals for all R&D, Federal, FFRDCs, Business, U&C, and Other Nonprofit. http://www.nsf.gov/statistics

Industry performed research and development (R&D) as a percent of industry output
Data on industry performed R&D are from the National Science Foundation. Data on industry output, defined as the state gross domestic product of the industrial sector, are from the Bureau of Economic Analysis. http://www.nsf.gov/statistics/http://www.bea.gov/regional/gsp/

Research and development (R&D) as a percent of gross domestic product (GDP)
International data on R&D as a percent of GDP are from the United Nations Educational, Scientific and Cultural Organization (UNESCO). The statistic measures the gross expenditure on R&D (GERD). GERD is the total intramural expenditure on R&D performed on the national territory during a given period (OECD, Frascati Manual, 2002). Data for Massachusetts' R&D as a percent of GDP are from the National Science Foundation and the Bureau of Economic Analysis. http://stats.uis.unesco.org

8. Performers of Research and Development

Data for the LTS are from the National Science Foundation's table of all R&D funds by state, performing sector, and source of funds. Data used are the totals for all R&D, Federal, FFRDCs, Business, U&C, and Other Nonprofit. http://www.nsf.gov/statistics. International data are from the United Nations Educational, Scientific and Cultural Organization.

9. Academic Article Output

Data are from the National Science Foundation's (NSF) Science and Engineering Indicators. The NSF obtained its information on science and engineering articles from the Thomson Scientific ISI database. http://www.nsf.gov/statistics/seind08/

10. Patenting

United States Patent and Trademark Office (USPTO) patents granted
The count of patents granted by state are from the US Patent and Trademark Office (USPTO).The number of patents per year are based on the date patents were granted. http://www.uspto.gov.

Patents published under the Patent Cooperation Treaty
International patents published under the Patent Cooperation Treaty are from the World Intellectual Property Organization (WIPO). Intellectual property data published in this report are taken from the WIPO Statistics Database, which is primarily based on information provided to WIPO by national/regional IP offices and data compiled by WIPO during the application process of international filings through the Patent Cooperation Treaty, the Madrid System and the Hague System. The number of patents per year are based on the date of publication. http://www.wipo.net

11. Patenting by Field

The count of patents granted by state and patent class are from the US Patent and Trademark Office (USPTO).The number of patents per year are based on the date the patents were granted. Patents in "computer and communications" and "drugs and medical" are based on categories developed by in Hall, B. H., A. B. Jaffe, and M. Tratjenberg (2001). "The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools." NBER Working Paper 8498. Patents in "advanced materials" and "analytical instruments and research methods" are based on categories developed by MTC's John Adams Innovation Institute. The "Business methods" category has its own USPTO patent class. http://www.uspto.gov

12. Technology Licensing

Data on licensing agreements are from the Association of University Technology Managers (AUTM). Institutions participating in the survey are AUTM members. The Massachusetts institutions included in the 2009 AUTM survey are listed below. http://www.autm.net

Hospitals and nonprofit research institutes	Universities
Beth Israel Deaconess Medical Center	Tufts University
Brigham and Women's Hospital	Univ. of Massachusetts
CBR Institute for Biomedical Research	Northeastern University
Children's Hospital Boston	Harvard University
Dana-Farber Cancer Institute	MIT
New England Medical Center	Boston U./Boston Medical Ctr.
St. Elizabeth's Medical Center of Boston	
Massachusetts General Hospital	
Schepens Eye Research Institute	
Tufts Medical Center	
Woods Hole Oceanographic Institution	

13. Small Business Innovation Research (SBIR) Awards

This indicator includes SBIR award data, not including Small Business Technology Transfer (STTR) awards. Data are accessed through the US Small Business Administration's Tech-Net database. http://tech-net.sba.gov/

14. Regulatory Approval of Medical Devices and Pharmaceuticals

Medical devices approvals
Data regarding medical device approvals in the US are provided by the US Food and Drug Administration. Medical device companies are required to secure premarket approvals (PMAs) before intricate medical devices are allowed market entry. A 510(k) is an approval sought by a company for a device that is already on the market and is looking for approval on components that do not affect the type of device, such as new packaging or new name. http://www.fda.gov

Drug approvals
Data on the number of drug approvals are from the Pharmaceutical Research and Manufacturers of America's publication "New Drug Approvals in 2010." http://www.phrma.org

15. Business Formation

New business establishment openings
Data are from the Business Employment Dynamics database of the Bureau of Labor Statistics. http://www.bls.gov/bdm

Entrepreneurial activity
Data are from the Kauffman Foundation, as published in the 2010 Kauffman Index of Entrepreneurial Activity. Data represent the percent of the adult, non-business owner population that starts a business in the given time span. Data are calculated using the Census Bureau's Current Population Survey. http://www.kauffman.org/research-and-policy/kauffman-index-of-entrepreneurial-activity.aspx

Net change in business establishments in the key industry sectors
The net change in business establishments was calculated using the Bureau of Labor Statistics' (BLS) Quarterly Census of Employment and Wages. Definitions for each key industry sector are in Appendix B. http://www.census.gov/econ/cbp/index.html

Spinout companies
Data on spinout companies are from the Association of University Technology Managers (AUTM). Institutions participating in the survey are all AUTM members. http://www.autm.net

16. Initial Public Offerings and Mergers and Acquisitions

Initial public offerings (IPOs)
The number and distribution by industry sector of filed initial public offerings (IPOs) by state and for the US are from Renaissance Capital's IPOHome.com. http://www.ipohome.com

Data on venture-backed IPOs for 2010 are from the National Venture Capital Association (NVCA).

Mergers & acquisitions (M&As)
Data on total number of M&As are from FactSet Mergerstat, LLC. M&A data represent all publicly announced mergers and acquisitions. http://www.mergerstat.com

17. Federal Funding for Academic, Nonprofit, and Health R&D

Federal expenditures for academic and nonprofit research and development (R&D)
Data are from the National Science Foundation's table of all R&D funds by state, performing sector, and source of funds. Data used are the entries for federal funding for universities and nonprofits, excluding university and nonprofit federally funded research and development centers (FFRDCs). http://www.nsf.gov/statistics

National Institutes of Health (NIH) funding per capita and average annual growth rate
Data on federal health R&D are from the NIH. The NIH annually computes data on funding provided by NIH grants, cooperative agreements and contracts to universities, hospitals, and other institutions. The figures do not reflect institutional reorganizations, changes of institutions, or changes to award levels made after the data are compiled. The figures also do not reflect health R&D spending by other federal agencies, such as DoD, DoE, EPA, and VA. http://www.nih.gov

18. Industry Funding of Academic Research

Data are from the National Science Foundation's Survey of R&D Expenditures at Universities and Colleges. Since FY 1998, respondents have included all eligible institutions. http://www.nsf.gov/statistics/srvyrdexpenditures/

19. Venture Capital (VC)

Data for total VC investments, VC investments by industry activity, and distribution by stage of financing are provided by PricewaterhouseCoopers (PwC) and the National Venture Capital Association (NVCA) in the MoneyTree Report. http://www.pwcmoneytree.com. Industry category designations are determined by PwC and NVCA. Definitions for the industry classifications and stages of development used in the MoneyTree Survey can be found at the PwC website. http://www.pwcmoneytree.com/moneytree/nav.jsp?page=definitions

20. Education Level of the Workforce

For this indicator, the workforce is defined as the population ages 25-65. Data on educational attainment of this population are from the US Census Bureau, Current Population Survey, Annual Social and Economic Supplement, 2005 through 2010. Figures are three year rolling averages. Data on employment rate by educational attainment are based on the full-time employment rate of the workforce. http://www.census.gov/hhes/www/cpstc/cps_table_creator.html

21. K-16 Education

TIMSS science scores
Trends in International Math and Science Study (TIMSS) is the product of a comparative assessment conducted every four years at the fourth and eighth grade levels. TIMSS is carried out by the International Association for the Evaluation of Educational Attainment and managed and directed by the International Study Center at Boston College. TIMMS involves 59 countries and 8 benchmarking regions including Massachusetts. http://timss.bc.edu/.

High school attainment by the population ages 19-24
Data on high school attainment are from the US Census Bureau, Current Population Survey, Annual Social and Economic Supplement, 2007 through 2011. Figures are three year rolling averages. http://www.census.gov/hhes/www/cpstc/cps_table_creator.html

College degrees conferred
International data are from the United Nations Educational, Scientific and Cultural Organization from the series "Total graduates in all programmes. Tertiary. Total." Tertiary corresponds to higher education, the definition of which can be found in the International Standard Classification of Education. Data for the US states comes from the National Center for Education Statistics using the sum of all degrees conferred at the bachelor's level or higher.

22. Public Investment in K-16 Public Education

This indicator looks only at public investments in education, but it should be noted that Massachusetts is unusual in the size of the private education sector. Forty-three percent (198,000 of 463,000) of higher education students attend public institutions in Massachusetts compared to 72% nationally with the remainder attending non-public institutions. These figures are from the National Center for Education Statistics (NCES), Integrated Postsecondary Education Data System (IPEDS) Enrollment Survey using the NCES population of institutions available at webcaspar.nsf.gov. While private higher education is an export industry in Massachusetts, 48% of Massachusetts high school graduates indicate that they will attend public higher education institutions compared to 32% indicating they will attend private institutions, with the remainder not attending college. This difference is even more dramatic for Hispanics (50% and 18% respectively), a growing component of the Massachusetts population. These figures are from the Massachusetts Department of Education, Plans of High School Graduates, Class of 2008. http://www.doe.mass.edu/infoservices/reports/hsg/data.html?yr=08

Per pupil spending in K-12
Public elementary & secondary school finance data are from the US Census Bureau. Figures are presented in 2010 dollars. Data excludes payments to other school systems and non K-12 programs. http://www.census.gov/govs/www/school.html

State higher education appropriations per FTE
Data on public higher education appropriations per full-time equivalent (FTE) student is provided by the State Higher Education Executive Officers' State Higher Education Finance (SHEF). The data consider only educational appropriations—state and local funds available for public higher education operating expenses, excluding spending for research, agriculture, and medical education and support to independent institutions and students. The SHEF Report employs three adjustments for purposes of analysis: Cost of Living Adjustment (COLA) to account for differences among the states, Enrollment Mix Index (EMI) to adjust for the different mix of enrollments and cost among types of institutions across the states, and the Higher Education Cost Adjustment (HECA) to adjust for inflation over time. More detailed information about each of these adjustments can be found on the SHEEO website: http://www.sheeo.org/finance/shef-home.htm.

Per pupil investments in public education, international comparison
This indicator compares per pupil investments in education relative to per capita GDP. International data are from the United Nations Educational, Scientific, and Cultural Organization. The countries selected are the highest ranking for this measure among high income nations as defined by the World Bank. According to the World Bank, "economies are divided among income groups according to 2008 gross national income (GNI) per capita, calculated using the World Bank Atlas method. The groups are: low income, $975 or less; lower middle income, $976–3,855; upper middle income, $3,856–11,905; and high income, $11,906 or more." For information on the World Bank Atlas method see http://go.worldbank.org/QEIMY0ALJ0.

State data was created by aggregating data on different educational levels. Per pupil spending on public K-12 was obtained from the US Census Bureau. The number of K-12 students enrolled in public school and spending on public higher education was obtained from the National Center for Education Statistics (NCES). The numbers of full-time equivalent postsecondary students in public schools are from the State Higher Education Executive Officers (SHEEO).

23. Science, Technology, Engineering, and Math (STEM) Career Choices and Degrees

Intended major of high school seniors
The intended majors of high school students is measured as the preference marked by students taking the Scholastic Aptitude Test (SAT) in Massachusetts and the LTS. Data are from The College Board, Profile of College Bound Seniors. Students are counted once no matter how often they tested, and only their latest scores and most recent Student Descriptive Questionnaire (SDQ) responses are summarized. The college-bound senior population is relatively stable from year to year; moreover, since studies have documented the accuracy of self-reported information, SDQ information for these students can be considered an accurate description of the group. http://www.collegeboard.com

STEM degrees
Data about degrees conferred by field of study are from the National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS) Completions Survey using the National Science Foundation (NSF) population of institutions. Data were accessed through the NSF WebCASPAR website. http://caspar.nsf.gov. Fields are defined by 2-digit Classification of Instructional Program (CIP), listed below.

- Science: 26-Biological & Biomedical Sciences and 40-Physical Sciences
- Technology: 11-Computer & Information Science & Support Services
- Engineering: 14-Engineering
- Math: 27-Mathematics & Statistics

24. Talent Flow and Attraction

Net population change
Data on population growth rate by state and the US, as well as total foreign and domestic migration data, are from the US Census Bureau's Population Estimates Program. This dataset is an annual release that uses estimates of the total population as of July 1 for the respective calendar year. http://www.census.gov/popest/datasets.html http://www.census.gov/popest/archives/1980s/80s_st_totals.html

Relocations to LTS by college educated adults
Data on population mobility come from the American Community Survey table BO7009: "Residence one year ago by educational attainment, persons ages 25 and older." This is the number of people moving in and includes no information about the number moving out. It can be used as a measure of the ability to attract talent. http://factfinder.census.gov

25. Housing Affordability

Housing Price Index
Housing price data are from the Federal Housing Finance Agency's Housing Price Index (HPI). Figures are four-quarter percent changes in the seasonally adjusted index. The HPI is a broad measure of the movement of single-family house prices. The HPI is a weighted, repeat-sales index that is based on repeat mortgage transactions on single-family properties whose mortgages have been purchased or securitized by Fannie Mae or Freddie Mac since January 1975 [technical description paper available at: http://www.fhfa.gov/webfiles/896/hpi_tech.pdf].

Housing affordability
Housing affordability figures are from the US Census Bureau, American Community Survey. The **Index** includes data from table R2515: "Percent of Renter-Occupied Units Spending 30 Percent or More of Household Income on Rent and Utilities," and R2513: "Percent of Mortgaged Owners Spending 30 Percent or More of Household Income on Selected Monthly Owner Costs." http://factfinder.census.gov

APPENDIX B

INDUSTRY SECTOR DEFINITIONS

The **Index** makes use of four- , five- and six-digit North American Industry Classification System (NAICS) codes to define key industry sectors of the Massachusetts Innovation Economy. The **Index**'s key industry sector definitions capture traded-sectors that are known to be individually significant in the Massachusetts economy. Consistent with the innovation ecosystem framework, these sector definitions are broader than 'high-tech'. Strictly speaking, clusters are overlapping networks of firms and institutions which would include portions of many sectors, such as Postsecondary Education and Business Services. For data analysis purposes the **Index** has developed NAICS-based sector definitions that are mutually exclusive.

Modification to Sector Definitions

The eleven key industry sectors as defined by the **Index** reflect the changes in employment concentration in the Massachusetts Innovation Economy over time. For the purposes of accuracy, several sector definitions were modified for the 2007 edition. The former "Healthcare Technology" sector was reorganized into two new sectors: "Bio-pharmaceuticals, Medical Devices and Hardware" and "Healthcare Delivery." The former "Textiles & Apparel" sector was removed and replaced with the "Advanced Materials" sector. While "Advanced Materials" does not conform to established criteria, it is included to in an attempt to quantify and assess innovative and high-growing business activities from the former "Textiles & Apparel" sector.

With the exception of Advanced Materials, sectors are assembled from those interrelated NAICS code industries that have shown to be individually significant according to the above measures. In the instance of the Business Services sector, it is included because it represents activity that supplies critical support to other key sectors. In the **2009 Index**, the definition of Business Services was expanded to include 5511-Management of companies and enterprises. According to analysis by the Bureau of Labor Statistics, this category has at least twice the all-industry average intensity of technology-oriented workers. All time-series comparisons use the current sector definition for all years, and, as such, may differ from figures printed in prior editions of the **Index**. The slight name change in 2009 of the Bio-pharma and Medical Devices sector does not reflect any changes in the components that define the sector.

Advanced Materials

3133	Textile and Fabric Finishing and Fabric Coating Mills
3222	Converted Paper Product Manufacturing
3251	Basic Chemical Manufacturing
3252	Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing
3255	Paint, Coating, and Adhesive Manufacturing
3259	Other Chemical Product and Preparation Manufacturing
3261	Plastics Product Manufacturing
3262	Rubber Product Manufacturing
3312	Steel Product Manufacturing from Purchased steel
3313	Alumina and Aluminum Production and Processing
3314	Nonferrous Metal (except Aluminum) Production and Processing

1. Seven-digit NAICS are apportioned to this sector based on more detailed industry data from one of two US Census Bureau sources: County Business Patterns or the Economic Census.

Bio/Pharmaceuticals, Medical Devices & Hardware

3254	Pharmaceutical and Medicine Manufacturing
3391	Medical Equipment and Supplies Manufacturing
6215	Medical and Diagnostic Laboratories
42345	Medical Equip. & Merchant Wholesalers
42346	Ophthalmic Goods Merchant Wholesale
54171	Physical, engineering, and biological research

With 2002 NAICS, apportioned based on 5417102 Biological R&D
With 2007 NAICS, apportioned based on 541711 R&D in Biotechnology and 5417122 R&D in Other Life Sciences[1]

334510	Electro Medical Apparatus Manufacturing
334517	Irradiation Apparatus Manufacturing

Business Services

5411	Legal Services
5413	Architectural, Engineering, and Related Services
5418	Advertising & Related Services
5511	Management of Companies
5614	Business Support Services

Computer & Communications Hardware

3341	Computer and Peripheral Equipment Manufacturing
3342	Communications Equipment Manufacturing
3343	Audio and Video Equipment Manufacturing
3344	Semiconductor and Other Electronic Component Manufacturing
3346	Manufacturing and Reproducing Magnetic and Optical Media
3359	Other Electrical Equipment and Component Manufacturing

Defense Manufacturing & Instrumentation

3329	Other Fabricated Metal Product Manufacturing
3336	Engine, Turbine, and Power Transmission Equipment Manufacturing
334511	Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing
334512	Automatic Environmental Control Manufacturing for Residential, Commercial, and Appliance Use
334513	Instruments and Related Products Manufacturing for Measuring, Displaying, and Controlling Industrial Process Variables
334514	Totalizing Fluid Meter and Counting Device Manufacturing
334515	Instrument Manufacturing for Measuring and Testing Electricity and Electrical Signals
334516	Analytical Laboratory Instrument Manufacturing
334518	Watch, Clock, and Part Manufacturing
334519	Other Measuring and Controlling Device Manufacturing
3364	Aerospace Product and Parts Manufacturing

Diversified Industrial Manufacturing

3279	Other Nonmetallic Mineral Product Manufacturing
3321	Forging and Stamping
3322	Cutlery and Handtool Manufacturing
3326	Spring and Wire Product Manufacturing
3328	Coating, Engraving, Heat Treating, and Allied Activities
3332	Industrial Machinery Manufacturing
3333	Commercial and Service Industry Machinery Manufacturing
3335	Metalworking Machinery Manufacturing
3339	Other General Purpose Machinery Manufacturing
3351	Electric Lighting Equipment Manufacturing
3353	Electrical Equipment Manufacturing
3399	Other Miscellaneous Manufacturing

Financial Services

5211	Monetary Authorities - Central Bank
5221	Depository Credit Intermediation
5231	Securities and Commodity Contracts Intermediation and Brokerage
5239	Other Financial Investment Activities
5241	Insurance Carriers
5242	Agencies, Brokerages, and Other Insurance Related Activities
5251	Insurance and Employee Benefit Funds
5259	Other Investment Pools and Funds

Healthcare Delivery

6211	Offices of Physicians
6212	Offices of Dentists
6213	Offices of Other Health Practitioners
6214	Outpatient Care Centers
6216	Home health care services
6219	Other ambulatory health care services
622	Hospitals

Postsecondary Education

6112	Junior Colleges
6113	Colleges, Universities, and Professional Schools
6114	Business Schools and Computer and Management Training
6115	Technical and Trade Schools
6116	Other Schools and Instruction
6117	Educational Support Services

Scientific, Technical, & Management Services

5416	Management, Scientific, and Technical Consulting Services
5417	Scientific Research and Development Services * *Minus the portion apportioned to the Bio sector
5419	Other Professional, Scientific, and Technical Services

Software & Communications Services

5111	Newspaper, Periodical, Book, and Directory Publishers
5112	Software Publishers
5171	Wired Telecommunications Carriers
5172	Wireless Telecommunications Carriers (except Satellite)
5174	Satellite Telecommunications
5179	Other Telecommunications
5182	Data Processing, Hosting, and Related Services
5415	Computer Systems Design and Related Services
8112	Electronic and Precision Equipment Repair and Maintenance

With 2002 NIACS add 516110 Internet publishing and broadcasting and 518112 Web search portals
With 2007 NIACS add 51913 Internet publishing and broadcasting and web search portals

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