Public-Private Partnerships in Action:

The Statewide Impact of the Massachusetts Life Sciences Center on the Life Sciences Ecosystem

Authored by: TEConomy Partners, LLC and Mass Economics
Prepared for: The Massachusetts Life Sciences Center

I am pleased to present *Public-Private Partnerships in Action: The Statewide Impact of the Massachusetts Life Sciences Center on the Life Sciences Ecosystem*, which analyzes the economic and scientific impact of the Massachusetts Life Sciences Center (MLSC) since the inception of the Massachusetts Life Sciences Initiative in 2008. There is no shortage of reports or data that present the case for Massachusetts as the world's leading life sciences ecosystem.

This report is different.

Through our engagement with a consultant team, we have sought to independently evaluate and assess the unique, incontrovertible contributions the Center has made to support the growth, development, and vitality of the Massachusetts life sciences ecosystem. In short, we wanted to know "but for" the investments and activities of the MLSC, how might the ecosystem have evolved?

The report that follows is the result of months of engagement by the consultant team, gathering and evaluating data from primary and secondary sources. This rigorous analysis not only provides a sense of economic and scientific development, it also begins to provide a measure of the return on the significant public investments made by the MLSC over the past ten years. I am deeply grateful to our partners, collaborators, and grantees for their time, data, and transparency that significantly contributed to the integrity of the analysis.

As a quasi-governmental authority, the MLSC is unique in our investment strategy and approach. Our mission is to advance both the scientific and economic development of the life sciences industry. As such, our work places us at the intersection of innovation, entrepreneurship, academic and workforce development, community and regional development, job creation and, of course, great science and positive patient outcomes. While we have many metrics that measure the efficacy of our actions, at the core, we approach our investments by looking at how best to serve individuals, communities, and regions across the entire Commonwealth.

I am very proud to report that, in relation to the overall Massachusetts life sciences ecosystem, the MLSC-supported companies have increased job growth, improved patent activity and commercialization, seen an increase in venture capital and federal funding, and conducted nearly 10 percent of the clinical trials in the Commonwealth. At the same time, our contributions increased collaborations between industry and academia, making innovation infrastructure such as research facilities, lab space, cutting-edge equipment, and incubators available across the state.

Perhaps most importantly, our investments are preparing the next generation of life sciences leaders through capital investments in K-12 education, community colleges, state colleges, and the University of Massachusetts system. We operate the largest state-run life sciences internship program in the nation. With this year's cohort, nearly 3,500 high school and college students will have had internship opportunities underwritten by the MLSC, and almost 25 percent will have gained full- or part-time employment directly as a result.

Looking forward, the future for our industry is bright and our commitment steadfast. With your ongoing support, we will continue our work to ensure Massachusetts remains a beacon to all those across the world who choose to make Massachusetts home and solve the biggest challenges in driving patient health.

Sincerely,

Travis McCready, President & CEO

Executive Summary

A Decade of Life Sciences Progress

The rise of Massachusetts as a national leader in life sciences development has continued to advance through the early decades of the 21st Century. The Commonwealth is now the top state in life sciences industry concentration—a key measure of industry specialization—and has risen from 6th in 2003 to 2nd in 2016 in total life sciences employment, behind only California. Along with its rising position in the number of life sciences jobs, Massachusetts is moving up in the quality of jobs being generated by its life sciences industry—a measure of wealth generation from life sciences activities—and now stands 2nd in the nation in average wages, ranking only behind New Jersey. It also moved up one position to 3rd in the nation in total life sciences wages paid.

Massachusetts' top-line growth in jobs and wages is the result of gains across all stages of innovation-led development, including robust research, technology commercialization, new firm formation, and the successful scale-up of companies. This reflects the strong foundations of Massachusetts' overall innovation ecosystem for life sciences development and its long-term ability to drive economic success. The Commonwealth stands out in comparison to other top life sciences states in the level of life sciences industry R&D, patent activity, and venture capital investments. Furthermore, despite a shrinking pool of federal research funds, driven by decreased funding for the National Institutes of Health (NIH), Massachusetts is holding its own in capturing these competitive awards for cutting-edge life sciences research projects that fuel new discoveries and innovations.

The Massachusetts Life Sciences Initiative: Enhancing the Life Sciences Ecosystem & the Commonwealth's Ability to Compete

Massachusetts' national leadership position in life sciences industry development reflects the confluence of market forces being supported by forward-looking public policy. Over the past decade, the Massachusetts Life Sciences Initiative (MLSI), a $1 billion initiative led by the newly formed Massachusetts Life Sciences Center (MLSC), has co-invested with life sciences stakeholders to help enhance capacity and accelerate growth. As this report details, these supportive public investments have made substantial contributions to the growth and advancement of Massachusetts' life sciences development in four broad programmatic areas:

* *Investing in innovation infrastructure for the future*
* *Fostering seed-stage and emerging industry development*
* *Scaling up life science companies*
* *Strengthening connections and the diversity of talent*

The MLSC's investments and its varied programs are supporting both near-term and more tangible development goals such as increasing jobs, investment, and commercialization through direct assistance to life sciences companies, as well as longer-term enhancements to the innovation ecosystem for life sciences, such as investing in innovation infrastructure. The program-by-program assessment of the overall economic impacts and direct contributions of MLSC programs reflect these two important and necessary approaches.

Across the MLSC programs, the most notable near-term contributions in life sciences development are the impact of the 115 companies MLSC directly assisted. The results are quite positive:

* Job growth among MLSC companies totaled 8,940 from their earliest reported employment at the time of assistance through 2016, reaching 50 percent growth compared with the overall industry job growth of 14 percent from 2009 through 2016.

* Venture capital investments in MLSC companies totaled $2.1 billion from 2009 through late 2017, reaching an average of $61 million invested per VC-funded company compared with an average of $39 million for all VC-funded life sciences firms in Massachusetts.

* Patent activity among innovative MLSC companies totaled 3,460, reaching 42 patents per firm, compared with about 6 patents per firm across the industry.

* SBIR/STTR awards for MLSC companies totaled 72 from 2009-16, with MLSC companies receiving awards that are on average nearly $1.2 million more than all life sciences companies thereby underscoring the success of MLSC companies in winning Phase II SBIR awards.

* Clinical trials sponsored by MLSC companies totaled 453, representing 9.1 percent of all industry-led clinical trials in Massachusetts during this period.

The MLSC's programmatic efforts and their broader impacts and outcomes are summarized in Figure ES-1. These include just some of the longer-term impacts of investments in innovation infrastructure, seed-stage industry development, and talent development and workforce connections realized by the MLSC investments thus far. These outcomes include: leveraging MLSC investments for additional funding, winning new federal research grants, fostering industry-university research collaborations, training STEM-related talent, connecting college and university students with life sciences companies, and advancing educational opportunities for a diverse population across the Commonwealth.

Implications for the Future

While Massachusetts has grown above expected national levels in both jobs and wages since 2009, its recent job growth is being outpaced by up-and-coming states, such as Utah and Texas, as well as more established life sciences leaders, such as North Carolina and California. Increased competition for life sciences development suggests that the MLSC remains as important today as it was when it was formed in 2008. However, in order to ensure that the Commonwealth remains nationally competitive, the MLSC must seek additional ways to foster and catalyze robust life sciences development in the years ahead. Looking forward, the MLSC should consider even more strategic investments by bringing together statewide scientific leadership from research institutions and industry to identify signature capacities needed to ensure Massachusetts remains competitive in fast-moving and emerging fields of life sciences, and to seek competitive proposals to ensure Massachusetts stays at the cutting-edge of innovation.

Fig. ES-1: Summary of the Direct Contributions of MLSC Programs

MLSC Themes	Investing in Innovation Infrastructure for the Future	Fostering Seed-Stage and Emerging Industry Development	Scaling Up Life Sciences Companies	Strengthening Connections and Diversity of Talent
Life Sciences Ecosystem Needs & Gaps	-Specialized infrastructure -Enhanced research capabilities -Accelerated commercialization -Space for new, growing co.'s -Connecting industry + univs.	-Validating technology -Valley of death in commercialization -Attracting capital -Building entrepreneurial management team	-Long development lead times -High research costs -Clinical trials -High costs to attract and train qualified workforce	-Generating a STEM talent pipeline -Need for work experience -Engage diverse talent base
MLSC Programs	-Capital Program for Research -Capital Program for Incubators/Accelerators -Neuroscience Consortium	-Accelerator Loans -Small Business Matching Grants -Milestone Achievement Program	-Tax Incentive Program	-STEM Eqpmt. and Supplies -Internship Challenge -Capital Program for Higher Education
Results	-$1.67 leveraged for every $1 invested -Major new federal research grants generated -Specialized scientific talent trained -New industry collaborations with researchers and start-up companies -901 jobs and $1.4 billion in private investment generated by start-up companies assisted	-52 companies assisted at early stage of development -$363 million in private and other investment generated -237 new jobs created	-8,703 new jobs added through FY 2016 by 63 companies actively involved or completed program -Estimated $60M in annual tax revenues generated by new hiring, helping to offset program incentives -Rated 3.9 on a 5 point scale in survey of industry participants pointing to significant value of program	-149 under-resourced schools assisted -Greater than $1M industry match for STEM equipment and supplies -3,170 college interns at 649 life science companies -20% of interns hired by host companies -New community college/ university degree programs, corporate customized training developed with expanded capabilities

Introduction

In 2008, Massachusetts made a $1 billion, ten-year commitment to solidify the state's prominence in life sciences industries. This ambitious effort, known as the Massachusetts Life Sciences Initiative (MLSI), created a body, the Massachusetts Life Sciences Center (MLSC), charged with carrying out the initiative. The MLSC, a quasi-public agency of the Commonwealth of Massachusetts, has been given a mandate to "expand life sciences-related employment opportunities in the Commonwealth and to promote health-related innovations by supporting and stimulating research and development, manufacturing and commercialization in the life sciences."

Over the past decade, the MLSC has co-invested with stakeholders to accelerate development of life sciences activity with a focus on four broad programmatic areas:

* *Investing in innovation infrastructure for the future*
* *Fostering seed-stage and emerging industry development*
* *Scaling up life science companies*
* *Strengthening connections and the diversity of talent*

As its initial ten-year funding authorization draws to a close, the MLSC commissioned an independent review to assess its impact on life sciences development in Massachusetts. The assessment presented here will provide a program-by-program evaluation as well as an assessment of the overall economic impact and return-on-investment of the MLSI. We choose 2009 as the base year for this study because although the bill creating MLSI was signed in 2008, the implementation of some provisions did not go into effect until 2009. Also, given the nature of this study, we thought it more appropriate to risk under-stating MLSI's impact by using 2009 as the base year rather than over-stating its impact by using 2008. The MLSC's contributions from its programs and investments are considered in the context of how Massachusetts' life science ecosystem is advancing in research, innovation, talent generation, and job and income creation.

The dynamics and requirements for advancing life sciences are distinct from other innovation-led industries for a number of reasons: close ties between industry, academia, and clinical care are required to advance innovation; the long, costly, and uncertain process of new product development due to the high level of regulatory oversight and often rigorous clinical trials required for product approvals; and the specialized nature of capabilities, facilities, and talent associated with life sciences research and development. (See Figure 1.) These dynamics require a specialized innovation ecosystem that creates cluster connections across basic sciences, technology development and commercialization, clinical research and testing, and scale-up.

In Section 1, we examine the development of the life sciences cluster in Massachusetts and compare the Massachusetts life sciences cluster with peer states. This history and comparison provides context on Massachusetts' life sciences specializations and the evolution of the cluster in the decade since the formation of the MLSC. We then examine the how the state's life sciences ecosystem—infrastructure that provides research funding, risk capital, intellectual property, and talent that supports life sciences activity—is advancing relative to national peers since the establishment of the MLSC. With this background, in Section 2 we examine specific programs and initiatives and assess their role in attracting funding, promoting innovative life sciences activities, and supporting job creation. In Section 3, we estimate the impact to date of the MLSI on job and wage growth in Massachusetts by comparing the trajectory of the life sciences cluster in the Commonwealth to peer states across the U.S.

For this report, we define "life sciences" activity as development, production, and distribution of products and services that improve human health, including drugs and pharmaceuticals, medical devices and equipment, research, testing and medical labs, and bioscience-related distribution. Figure 2 lists the specific industries under each of these sets of activities, i.e., sub-clusters. (See appendix table A-2 for list of industry definitions for the life sciences cluster.)

Fig. 1: Dynamics of Life Sciences Innovation Ecosystem

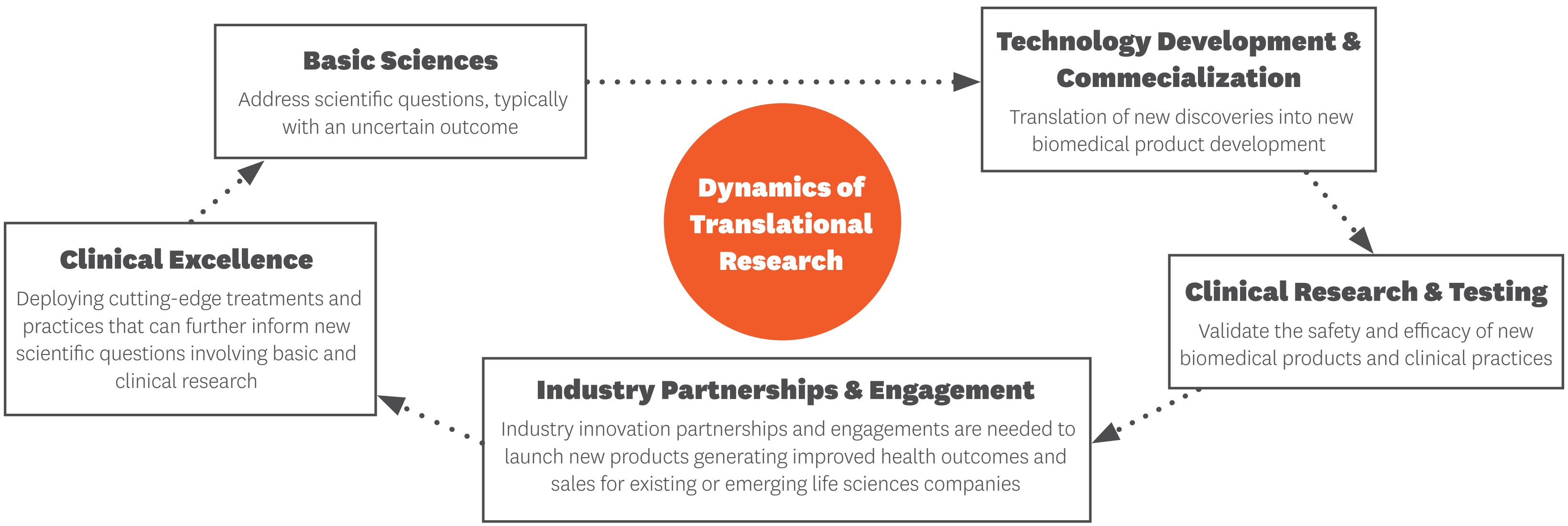


Fig. 2: Defining the Massachusetts Life Sciences Cluster

Drugs & Pharmaceuticals	Medical Devices & Equipment	Research, Testing & Medical Labs	Bioscience-related Distribution
* Pharma manufacturing * Diagnostic substances * Biopharmaceuticals * Vaccines	* Biomedical instruments * Electromedical equip. + devices * Healthcare products + supplies * Lab instrumentation	* Biotech + other life sciences R&D * Testing labs * Medical labs	* Biomedical equipment + supplies * Drugs + pharmaceuticals

Section 1 Life Sciences in Massachusetts

As of 2016, life sciences in Massachusetts employed 99,000 workers, the second highest among U.S. states, and generated $13.4 billion in wages, the third highest among states. (See Figure 3 below and the appendix for data sources.) The Commonwealth also ranked second in average cluster wage ($135,200), first in share of total jobs accounted for by life sciences (3.2%), and second in share of total wages accounted for by life sciences (6.4%). As shown in Figure 4, only Massachusetts and New Jersey rank in the top three states in life sciences jobs, share of total jobs, life sciences wages, share of total wages, and average wage.

This performance reflects the strong growth of the cluster since the early 2000s: between 2003 and 2016, Massachusetts added about 28,000 life sciences jobs and $7.5 billion in associated annual wages, accounting for 8.6% of the Commonwealth's job growth and 9.4% of its wage growth. Over this period, Massachusetts greatly outpaced national average job growth (39% versus 16% for the U.S. overall) and wage growth (56% versus 31%). In fact, although the Commonwealth is home to only about 2.5% of total U.S. employment, during this period it accounted for about one in eight net new jobs created in life sciences in the U.S.

Fig. 3: Life Sciences Employment and Wages for MA and Peer States (2003-2016)

Life Sciences Jobs

2003		2009		2016	
CA	213,800	CA	234,300	CA	274,800
NJ	97,000	NJ	97,400	MA	99,000
PA	90,900	PA	87,900	NJ	94,100
NY	81,000	MA	86,500	FL	85,000
IL	73,100	NY	79,600	TX	84,200
MA	71,000	FL	78,100	PA	84,000
FL	69,600	TX	74,100	NY	81,700
TX	63,600	IL	65,800	IL	69,900
NC	48,300	NC	59,900	NC	69,800
IN	47,300	IN	52,500	IN	52,000

Life Sciences Wages ($B)

2003		2009		2016	
CA	$16.4	CA	$24.1	CA	$35.3
NJ	$8.9	NJ	$11.3	NJ	$13.9
PA	$6.4	MA	$8.6	MA	$13.4
MA	$5.8	PA	$8.1	IL	$8.9
IL	$5.5	IL	$6.3	PA	$8.9
NY	$4.8	NY	$5.7	TX	$7.6
TX	$4.0	TX	$5.6	NY	$7.4
FL	$3.9	FL	$5.3	FL	$7.1
MI	$3.3	NC	$4.6	NC	$6.4
IN	$3.2	IN	$4.3	IN	$5.0

The Geography of Life Sciences in Massachusetts

The geographic footprint of the life sciences cluster is heavily oriented towards the eastern part of the state. (See Figure 5.) After adding about 11,000 jobs between 2009 and 2016, Middlesex County is now home to over 55% of the state's life sciences employment, with well-known concentrations in Cambridge (20,000 jobs), Bedford, Marlborough, and Waltham. Outside of Middlesex County, only Worcester County, home of UMass Medical and the Massachusetts Biomedical Initiatives incubator, has experienced significant life sciences job growth, adding 2,200 jobs since 2009, more than all other counties (excluding Middlesex) combined.

The Commonwealth's two key life sciences corridors—Route 128 (22,600 life sciences jobs as of 2016) and Interstate 495 (20,900 life sciences jobs)—account for about 45% of total life science activity, a proportion that has dropped slightly since 2009. Although growth along I-495 has slightly lagged growth on Route 128 (11% versus 14% since 2009), the strength of the corridor is critical to extending the western boundary of the Commonwealth's life sciences cluster. In terms of concentration, life science jobs account for a higher proportion of total jobs along I-495 (5.3% of all jobs; location quotient: 3.9) than along Route 128 (4.8% of all jobs; location quotient: 3.5). Route 128 activities are concentrated in medical devices and equipment (6,700; 28% of MA total) and research, testing, and medical labs (11,900; 22% of MA total) while I-495 activities are concentrated in medical devices and equipment (10,100 jobs; 42% of MA total) and bioscience-related distribution (3,100 jobs; 32% of MA total). West of the I-495 belt, there is significant life sciences

Fig. 4: Life Sciences Jobs and Wages Ranking by State

State	Jobs	LS Share of Total Jobs	Wages	LS Share of Total Wages	Average Wage
CA	1	7	1	4	3
MA	**2**	**1**	**3**	**2**	**2**
NJ	3	2	2	1	1
FL	4	15	8	15	17
TX	5	20	6	19	13
PA	6	9	5	9	6
NY	7	17	7	20	12
IL	8	11	4	10	4
NC	9	6	9	6	10
IN	10	4	10	3	8
MN	11	5	11	7	7
OH	12	18	14	17	19
MI	13	13	13	13	14
MD	14	8	12	8	5
TN	15	12	15	11	16
UT	16	3	20	5	20
WA	17	16	16	16	11
CO	18	10	17	12	9
GA	19	19	18	18	15
WI	20	14	19	14	18

Fig. 5: Life Sciences Employment in MA Overall (2016)

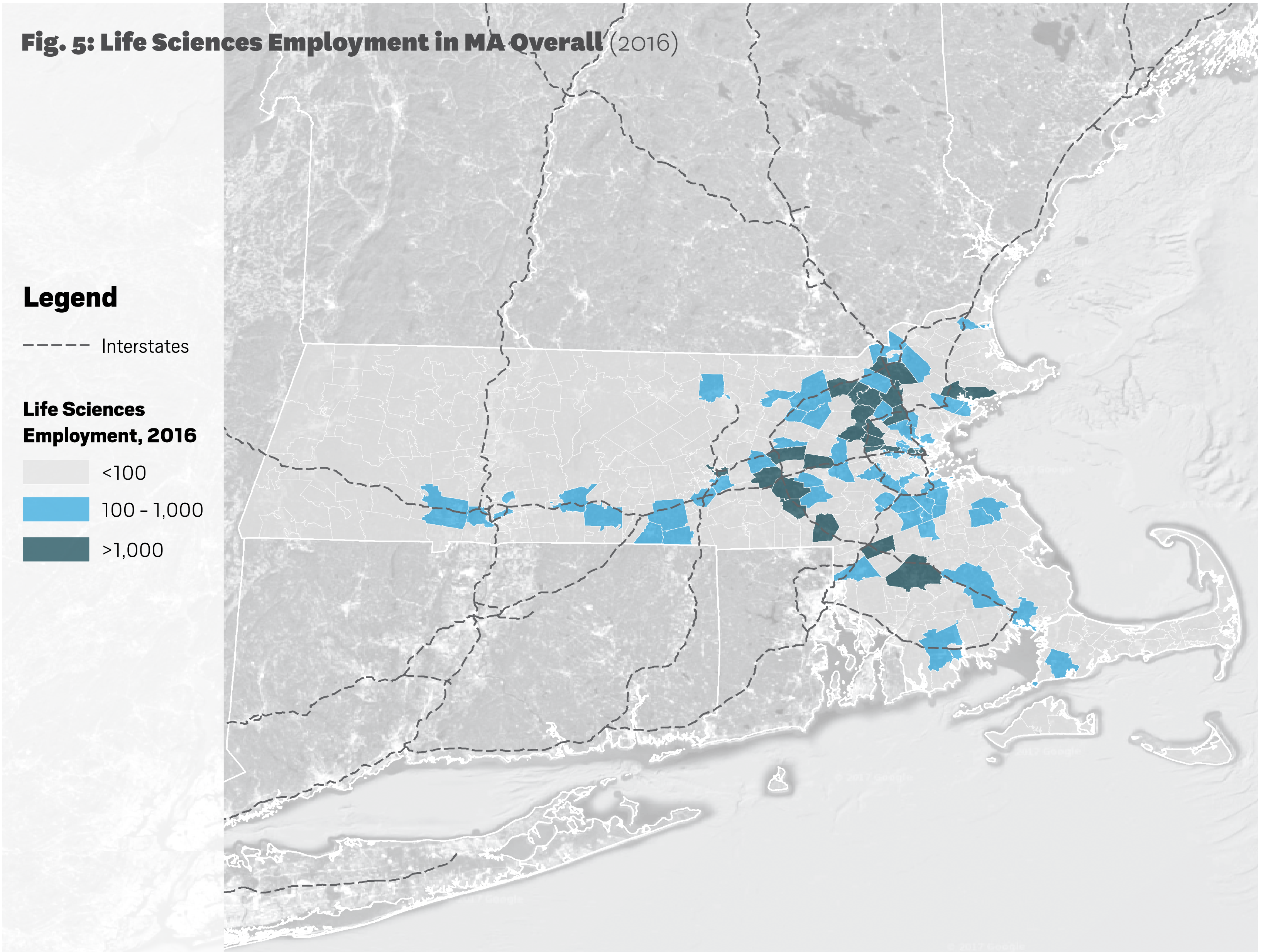
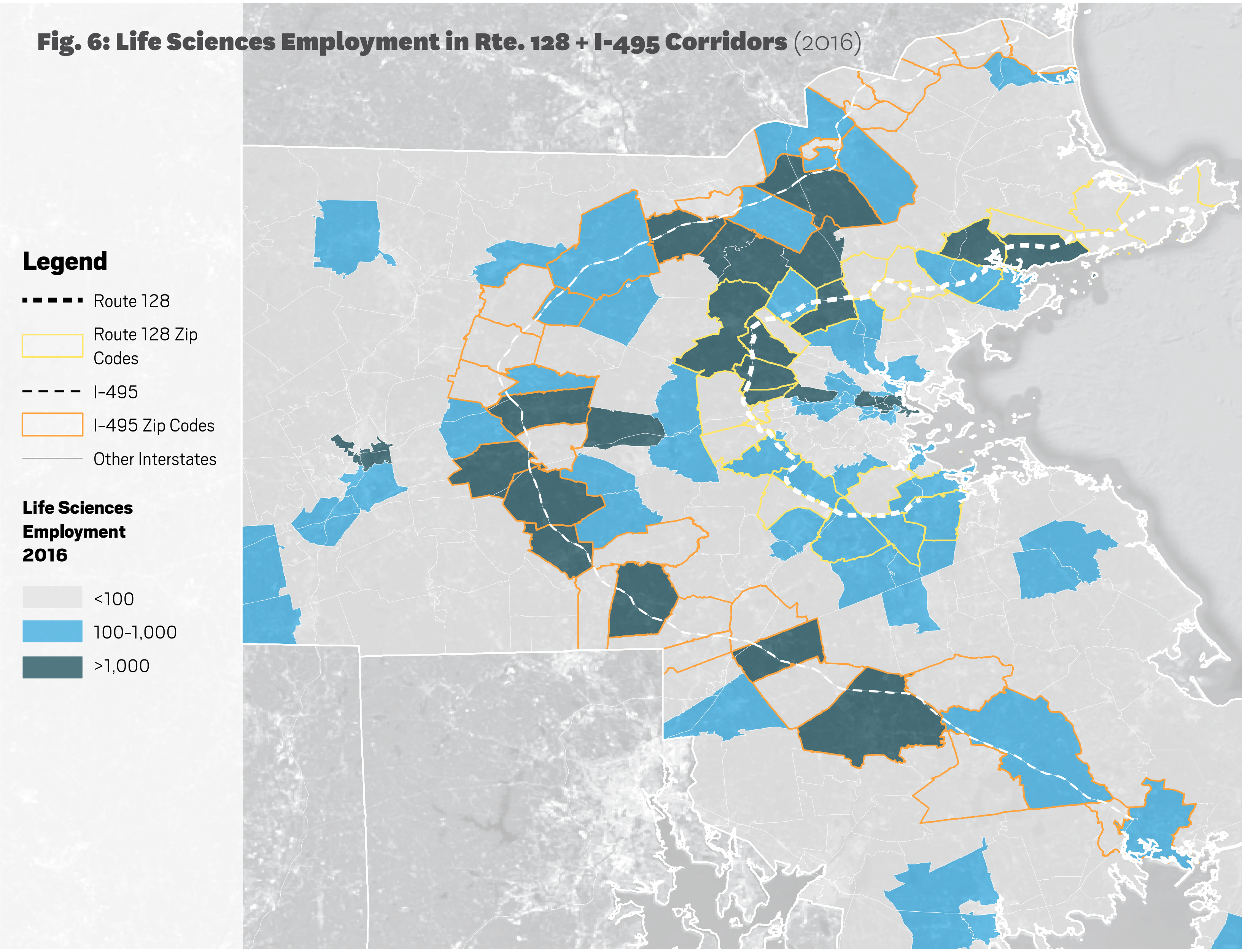


Fig. 6: Life Sciences Employment in Rte. 128 + I-495 Corridors (2016)



activity in Worcester County—which has about 9,000 total jobs and strong presence in all sub-clusters (medical devices and equipment; research, testing, and medical labs; drugs and pharmaceuticals; and bioscience-related distribution)—but only scattered life sciences activity west of the county. (See Figures 5 and 6.)

There is some evidence that the footprint of life sciences activity has expanded since the inception of the MLSC. Areas that historically have not been able to compete for life sciences jobs have accounted for a substantial portion of life science job growth in Massachusetts. As shown in Figure 7, in zip codes with the lowest life sciences specializations (i.e., those with location quotients less than 1.0) as of 2009, employment more than doubled between 2009 and 2016, rising from 6,700 to 14,800. In the most specialized life science zip codes (those with location quotients greater or equal to 3.0), job growth was only 6% in the same period. Overall, zip codes with the lowest specializations as of 2009 accounted for over 60% of the state's zip-code based job growth (8,000 of 12,900) through 2016.

Fig.7: Life Sciences Employment Growth by the Employment Concentration

Life Sciences Concentration, 2009	Life Sciences Jobs, 2009	Life Sciences Jobs, 2016	Growth Rate 2009-2016
LQ <1	6,700	14,800	119%
1 < LQ <3	11,800	12,700	7%
LQ >=3	67,000	71,000	6%
Total*	85,500	98,400	15%

* Zip code based employment totals are less than state totals due to employment assigned to the "statewide county" category, for which specific locations are unknown.

Long-Term Cluster Strength: Ecosystem Development Since 2009

Over the long term, life sciences job and wage growth will be strongly shaped by the strength of critical ecosystem supports in the Commonwealth. In this section we compare ecosystem developments in Massachusetts against those in a set of peer states—California, New Jersey, North Carolina, Indiana, Minnesota, Maryland, Utah, Florida, and Texas. (Appendix A provides a description of the data and methods used to select these peer states.) This assessment focuses on four key areas of ecosystem strength—research, risk capital, intellectual property, and talent. We find significant strengths and major gains in these measures since the inception of MLSI, but also areas for improvement.

Examples of Other States Making Significant Life Sciences Development Investments Over the Last Decade

* ***California:*** *$3 billion funding for California Institute for Regenerative Medicine*
* ***Maryland:*** *$1.1 billion funding for Bio2020*
* ***Texas:*** *$3 billion Cancer Prevention and Research Institute*

Research: Massachusetts is leading or among the top-tier of benchmark states in measures of life science R&D activity—including academic and industrial R&D—and receipt of critical NIH research funding. Massachusetts' universities had life science-related R&D expenditures that averaged $1.4 billion per year from 2009 through 2015 and relative to the size of its economy, place the state third among peers. And while NIH funding is declining at the national level, Massachusetts has actually had modest gains in recent years, making it one of only three states (with Maryland and North Carolina) to do so. Its leading and rapidly growing position in industrial research stands out with nearly 17% annual growth since 2009 and average levels of $6.7 billion per year from 2010 through 2015. (See Figure 8.)

Risk Capital: Companies and states are competing fiercely for vital pools of private risk capital, and Massachusetts is a clear winner when it comes to formal venture capital (VC) investments. The state's life science companies secured $17.8 billion in cumulative VC funding from 2009 through 2016, second only to California. This strong position has accelerated in recent years, with annual gains for Massachusetts well outpacing the nation though lagging behind states with much smaller base levels of investment—Utah and Florida. The state has seen a level increase—from 2011 to 2013 life sciences in Massachusetts averaged $1.8 billion in VC funding; and from 2014 through 2016 that average rose to $3.2 billion. In federal Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) award activity, Massachusetts is first among its peers in normalized award levels with four times the national level. However, annual growth in both awards and funding has slowed and now lags behind the nation and peer states. (See Figure 9.)

Intellectual Property: Massachusetts' life science industry and its colleges and universities are successfully translating life science R&D activities and funding resources into tangible innovations in the form of patents. Relative to the size of the state economy, Massachusetts is first among peer states in both patent applications and awards. The Commonwealth is patenting life science inventions at a level more than four times higher than the national average and these levels are growing at a rapid rate of more than 13 percent annually. In terms of absolute levels, Massachusetts inventors were awarded nearly 32,000 patents from 2009 through 2016, which falls well behind California at nearly 77,000, but well ahead of the next-largest life science patenting state, New Jersey (about 19,000). (See Figure 10.)

Talent: Massachusetts employs a high concentration of workers in primary life science-related occupations such as microbiologists, biochemists, epidemiologists, and biomedical engineers. The state is first among peer states in its concentration in these jobs relative to total employment. Its annual growth in occupational employment has been higher than that of the nation, but has lagged three peer states since 2009—Maryland, Indiana, and California. (See Figure 11.)

Fig. 8: Research - Peer State Comparison

	Metric	MA	U.S.	MA Rank (out of 10)
Industrial R&D, Life Sciences	Average Expenditures per $10M GDP, 2010-15	$152,200	$36,700	1
	Compound Annual Growth Rate (CAGR), 2010-15	16.7%	2.8%	1
University R&D, Life Sciences	Average Expenditures per $10M GDP, 2009-15	$32,300	$21,300	3
	CAGR, 2009-15	4.2%	3.0%	3
Business-financed University R&D, Life Sciences	Average Expenditures per $10M GDP, 2010-15	$1,400	$1,100	3
	CAGR, 2010-15	5.7%	5.2%	3
NIH Funding	Average Funding per $10M GDP, 2009-16	$59,100	$19,100	1
	CAGR, 2009-16	0.3%	-0.8%	3

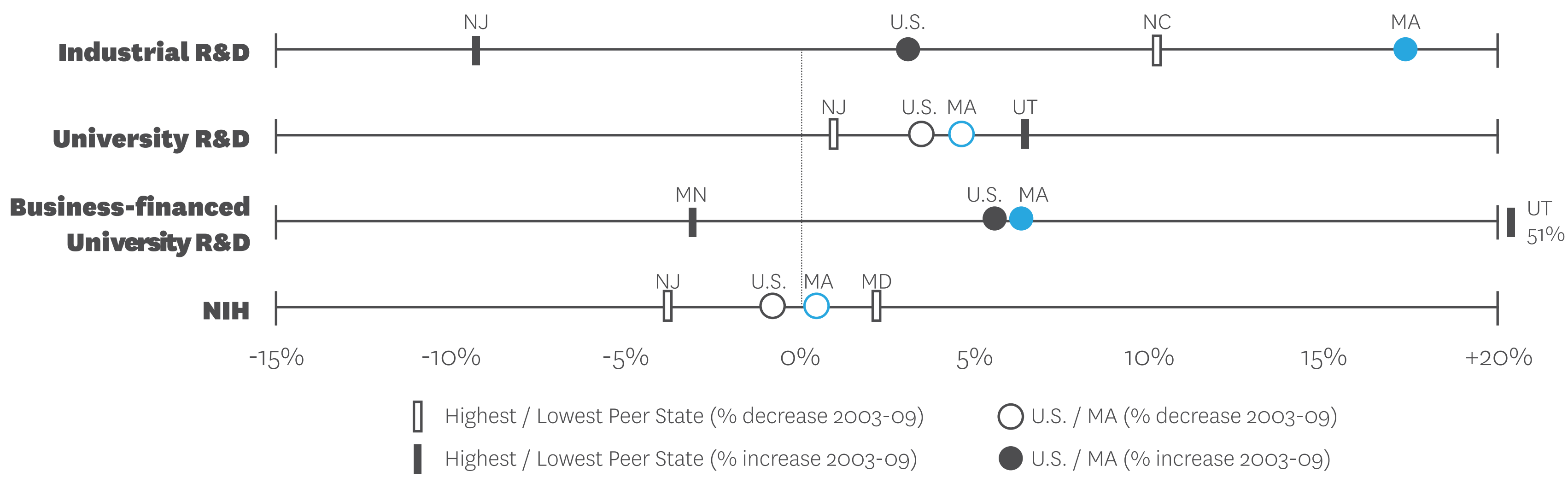


Fig. 9: Risk Capital - Peer State Comparison

	Metric	MA	U.S.	MA Rank (out of 10)
Venture Capital Investment in Life Sciences Companies	Average VC Investments per $10M GDP, 2009-16	$50,400	$6,800	1
	CAGR, VC Investments, 2009-16	12.5%	7.1%	3
	Average VC Deals per $1B GDP, 2009-16	0.47	0.09	1
	CAGR, VC Deals, 2009-16	-0.7%	0.6%	6
SBIR/STTR Awards in Life Sciences Companies	Avg. SBIR/STTR Funding per $10M GDP, 2009-16	$2,100	$500	1
	CAGR, SBIR/STTR Funding, 2009-16	3.8%	4.4%	8
	Avg. SBIR/STTR Funding per $1B GDP, 2009-16	0.34	0.08	1
	CAGR, SBIR/STTR Awards, 2009-16	0.5%	1.9%	9

Fig. 10: Intellectual Property - Peer State Comparison

Patenting in Life Science-related Classes

Metric	MA	U.S.	MA Rank (out of 10)
Avg. Annual Invented Patents per $B GDP, 2009-16	5.1	1.2	1
CAGR, 2009-16	13.4%	10.9%	3
Avg. Patent Applications per $B GDP, 2009-16	9.0	1.9	1
CAGR, Patent Applications, 2009-16	5.5%	2.8%	2

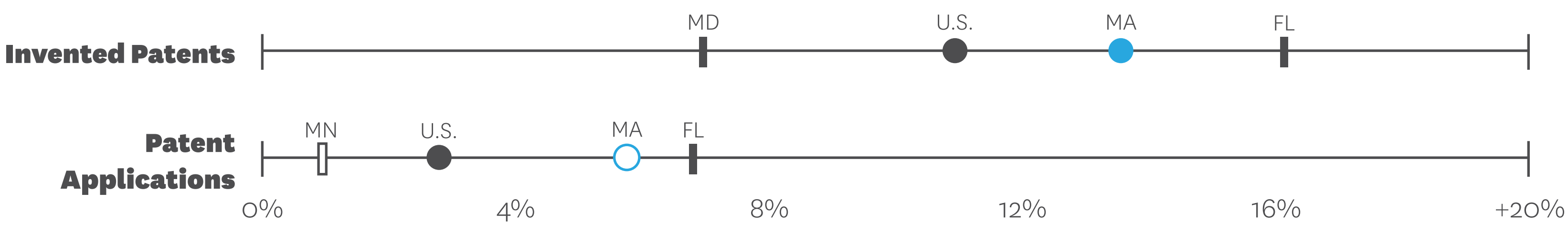
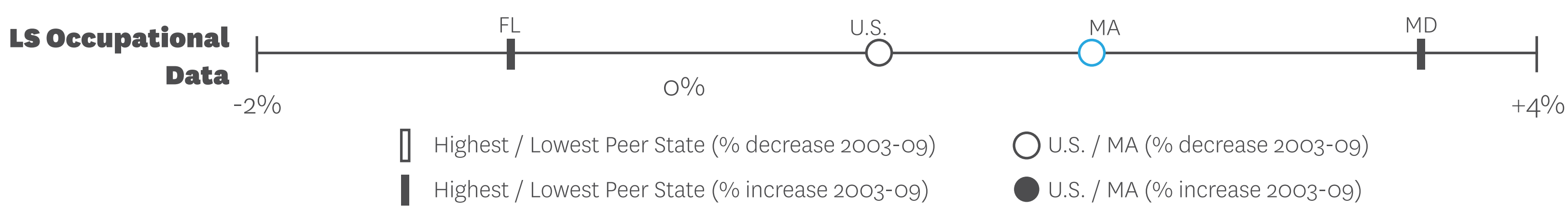


Fig. 11: Talent - Peer State Comparison

Life Science-related Occupational Employment

Metric	MA	U.S.	MA Rank (out of 10)
Avg. Annual Life Sci. Occupational Emp., 2009-16	40,800	735,800	3
Life Sci. Occupational Emp. as % of State Emp., 2009-16	1.25%	0.55%	1
CAGR, 2009-16	1.9%	0.8%	4



A high-functioning ecosystem for life sciences development requires each of these key areas to be strong and as shown in Figure 12, the Massachusetts' share of national U.S. total for each metric (4.1% to 19.9%) is much higher than would be predicted by the size of its economy (2.5% of U.S. jobs). In aggregate across the nine key metrics shown in Figure 13, Massachusetts has seen an increase in its share of national activity, from 10.9 percent in 2009 to 11.3 percent in 2016. If we weight the metrics by total value, Massachusetts increased its share from 7.6 percent in 2009 to 9.6 percent in 2016, largely because of large gains in share of venture capital dollars. But in areas such as NIH funding, where a shrinking pool of federal funds even threatens states like Massachusetts that routinely out-compete other states for awards; SBIR/STTR awards where Massachusetts' growth has slowed; and venture capital deal volume, which has slowed even while funding dollars have grown, the Commonwealth must continue to position itself for success to be ensured, particularly as competitor states are catching up.

Fig. 12: MA Life Sciences Ecosystem Summary

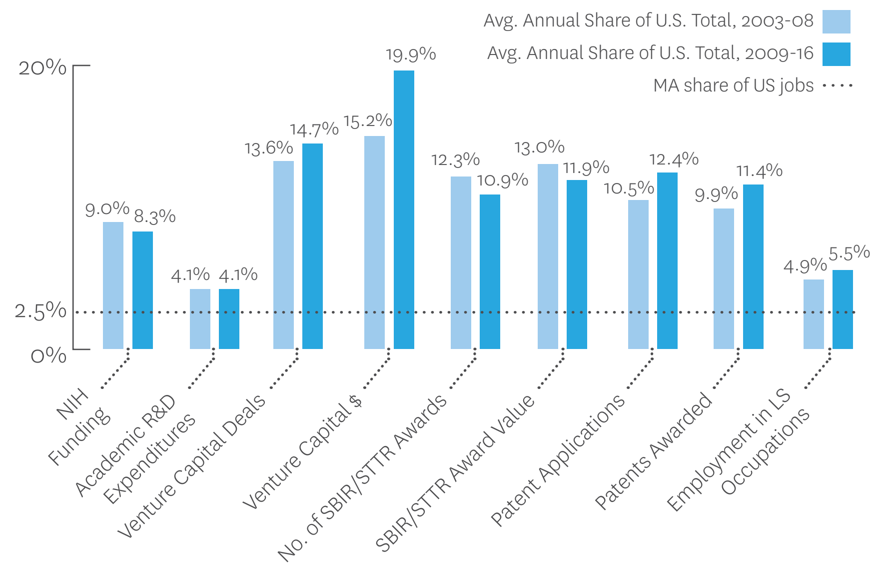
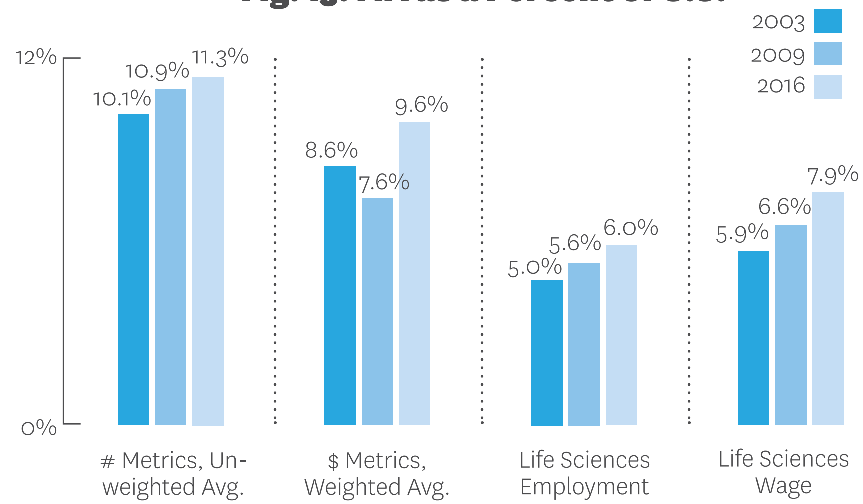


Fig. 13: MA as a Percent of U.S.



$ Metrics include Academic R&D Expenditures, Business Financed Academic R&D, NIH Funding, SBIR/STTR Award Values, and Venture Capital $

Metrics include Employment in LS Occupations, Patent Applications, Patents Awarded, SBIR/STTR Award #s, and Venture Capital Deals

Section 2 Direct Program Contributions

For almost a decade, the advancement of the Massachusetts life sciences cluster has been aided by the program activities and investments of the MLSC. The key question for this assessment is how these investments have contributed to the advancement of life sciences activities across the state.

A standard approach to evaluating program performance is to measure the use of resources in generating program activities relative to economic development or other target outcomes. To assess how the MLSC's programs have contributed to life sciences developments in the Commonwealth, we track (by program) levels and types of funded activities, activity progress and leverage, and outcomes in terms of both ecosystem development and jobs. This approach provides a transparent and direct method for evaluating the direct impact of individual MLSC programs. (See Figure 14.)

Value of Logic Models for Measuring Program Contributions

As the Kellogg Foundation explains in its Logic Model Development Guide, "the purpose of a logic model is to provide stakeholders with a road map describing the sequence of related events connecting the need for the planned program with the program's desired results."

W.K. Kellogg Foundation Logic Model Development Guide, January 2004, page 3, available at www.wkkf.org.

Advancing short- and long-term life sciences development requires investing across the stages of innovation—from research to commercialization to new company formation to scaling companies—as well as ensuring a robust talent pipeline to meet the needs of a growing and constantly innovating cluster. To support these outcomes, the MLSC has invested in four programmatic areas:

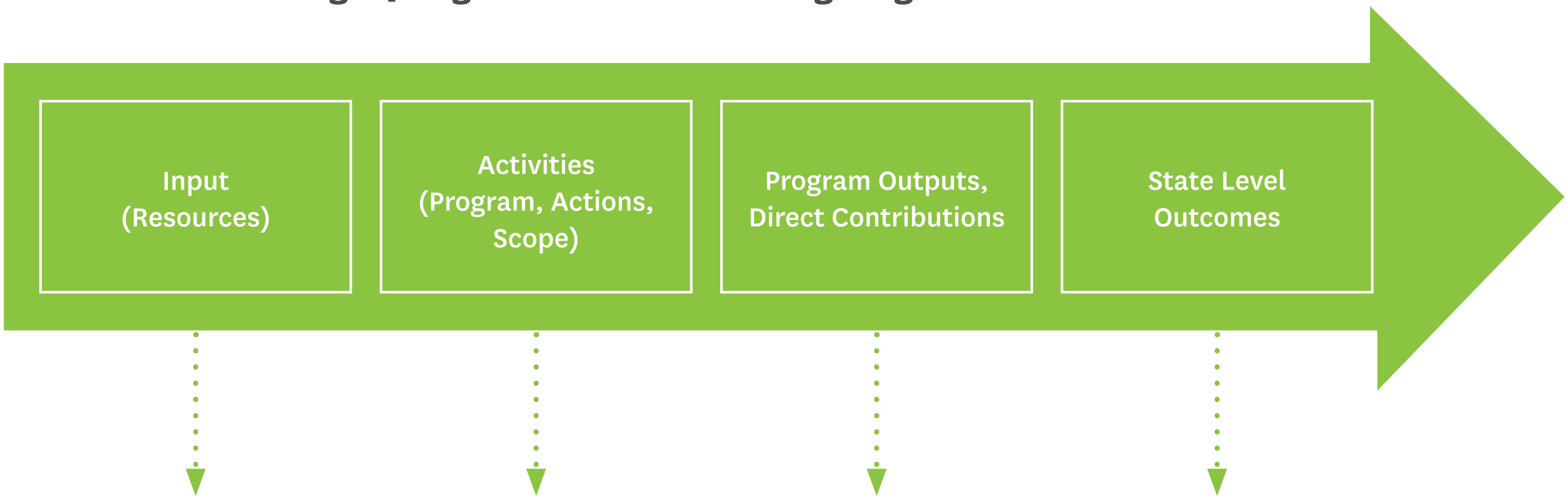
* *Investing in innovation infrastructure*
* *Fostering seed-stage and emerging industry development*
* *Scaling up life science companies*
* *Strengthening connections and the diversity of talent*

The first two programmatic areas position Massachusetts for long-term life sciences development and job growth, as research discoveries are commercialized and start-up companies take root and grow. The second two programmatic areas support near-term job creation and ensure a short- and long-term pipeline of qualified workers for life sciences industries.

Programmatic Area: Investing in Innovation Infrastructure

The pathway from a life science discovery to a new medical product or life science venture is often compared to a marathon with long development times and uncertainty of success. In addition, much of life sciences innovation is driven by complex science and rigorous regulatory oversight, involving clinical testing and post-approval monitoring. A necessary antecedent to life sciences innovation is researchers' and entrepreneurs' ability to access the unique, high-value equipment and facilities necessary to engage in scientific discovery.

Fig. 14: Logic Model for Evaluating Program Contributions



Funding levels by program and year

Specific grantees by year, with funding and types of funded activities

Grant-related progress by program

Example 1: Hiring goals for tax incentives

Example 2: Loan repayments on accelerated loan program

Additional funding leveraged on a project basis

Ecosystem:

New Products

Venture Capital

Licenses/Strategic Collaborations

Patent Awards

Research Funding

Jobs and Wages:

Jobs Created

Average Wages

80% of the most transformative drugs over the last 25 years resulted from collaborations between industry and academia.

Tufts Center for the Study of Drug Development, Public and Private Contributions to the R&D of the Most Transformational Drugs of the Last 25 Years, Jan. 2015.

The Capital Program for R&D Infrastructure:

Engaging Massachusetts research anchors to advance new scientific capacities to keep Massachusetts at the cutting-edge of life sciences advances and capabilities.

To run the life sciences marathon, states need the staying power of institutional research anchors, which are critical in generating innovative product leads, investing in signature research facilities, and educating and employing top talent. Institutional research anchors—found at academic medical centers, universities, non-profit research institutes and medical centers—are especially important in the development and testing of the cutting-edge technologies that are reshaping life sciences innovation (such as advanced diagnostics, regenerative medicine, and genomic-based precision medicine), as well as in novel, emerging fields like neuroscience and microbiomics.

Program Inputs: Through FY 2016, the MLSC has allocated $336 million to 23 capital research projects.

Program Outputs: MLSC funds were leveraged by $560 million of additional funding ($1.67 per $1.00 invested by the MLSC).

State-level Outcomes: 465 permanent scientific jobs in FY 2016 reported by all operational research facilities funded by the MLSC.

Broader Outcomes: Harder to gauge are program-generated advancements in Massachusetts' scientific capacities, many of which will take years to be realized. To assess these outcomes, we examined four projects that have been in operation for several years and received a combined $109 million from the MLSC:

* *Laboratory of Systems Pharmacology at Harvard Medical School*
* *Children's Center for Cell Therapy at Boston Children's Hospital*
* *Center for Personalized Cancer Therapy at UMass Boston in partnership with Dana Farber Cancer Center*
* *The Albert E. Sherman Center at UMass Medical School*

***Competing for new research funding*:** The Laboratory of Systems Pharmacology increased philanthropic funding by $7.2 million and federal (NIH, FDA, DoD DoE) research funding by $35 million, including new NIH-funded centers in systems biology and integrated network-based cellular signatures. The Children's Center for Cell Therapy at Boston Children's Hospital was able to leverage the enhancements supported by MLSC funding to win two NIH center grants; one to advance treatments for rare anemia, the other to make stem cell lines from patients with different types of blood disease.

Generating specialized scientific talent needed by research institutions and industry: Novel, interdisciplinary training in therapeutics advancement with internships in academic and industry settings is being advanced at Harvard's Laboratory of Systems Pharmacology, home to 35 full-time postdoctoral fellows and 25 part-time trainees from eight regional institutions across Massachusetts. At the Children's Center for Cell Therapy at Boston Children's Hospital, more than half of graduate students and post-doctoral fellows being trained enter industry careers, making Boston a hotspot for new stem cell therapies.

Creating new research capacities that industry and research institutions can tap: Genomic-related core facilities at the MLSC-supported Center for Personalized Cancer Therapy are being utilized by five start-up companies at UMass Boston's Venture Development Center. With its advanced preclinical facilities funded with MLSC capital grants, Children's Center for Cell Therapy at Boston Children's Hospital is involved in testing three cell-based drugs that have entered clinical trials, demonstrating a pathway for taking stem cell research out of the laboratory and into clinical testing.

Generating new discoveries leading to start-ups: There were 68 patent filings and eight life science spin-offs based on innovations made by faculty at the Sherman Center.

Facilitating a Neuroscience Consortium to fund and advance pre-clinical neuroscience research at Massachusetts academic and research institutions.

The MLSC acts as the facilitator for the Neuroscience Consortium, providing $250,000 of support in addition to in-kind resources such as staff time, to advance the initiative. The Consortium connects pharmaceutical company members with academic researchers to provide expedited access to the strong neuroscience research cluster concentrated in the Commonwealth.

- Consortium members have funded 25 proposals from academics for $6.25 million in pre-clinical research.
- The initiative is advancing industry-university research connections in Massachusetts with value propositions for industry such as greater efficiency, reduced costs, and increased access to leading research.
- Connecting researchers to both limited funding and an audience of industry specialists has resulted in researcher/industry partnerships beyond the Consortium.

Participant companies credit the MLSC's groundwork and facilitation in making the Consortium a reality.

- One consortium participant remarked "Our legal department would likely not have taken on the work to understand how to form such agreements across the industry participants and with the researchers and that alone would have made this a non-starter."

Capital Investment in Incubators and Accelerators: *Catalyzing translational life sciences development with specialized real estate investments that support new company growth and advance innovation partnerships.*

Life sciences development is accelerated when researchers and entrepreneurs have access to world-class equipment and facilities in an environment that advances communication and collaboration between industry and academia, and supports the incubation of ideas, product development, and new venture formation.

Program Inputs: Through FY 2016, the MLSC has awarded $25.7 million for nine incubators and accelerators across the Commonwealth.

Program Outputs: The majority of the award funding ($22 million) has gone to four projects tailored to the specific needs of their communities:

LabCentral in Cambridge - LabCentral pioneered a new approach to concierge services, plug-and-play lab space for high-growth-potential biotech companies that can benefit from partnerships with large biopharma companies.

M2D2 at UMass Lowell - The Massachusetts Medical Device Development Center (M2D2) at UMass Lowell assists inventors and entrepreneurs in bringing medical devices from the idea phase to production. Their approach, based on LabCentral's shared use model, forges partnerships between small, emerging companies and large, established medical device companies, with UMass Medical acting as a clinical and translational research partner. Support from the MLSC was used to build 10,000 square feet of newly equipped wet-lab space at the incubator. M2D2 is also helping anchor a new 14-acre designated development district in downtown Lowell.

North Shore InnoVentures in Beverly - The incubator facilities at North Shore InnoVentures fill a gap in access to the types of modern scientific equipment and state-of-the-art laboratories that support product development, life science incubation, and workforce development.

Bay State Innovation Center (TechSpring) in Springfield - TechSpring is a clinically-oriented health IT initiative to de-risk start-up and corporate health innovations in a real-world environment, with mentoring support provided by clinicians and executives at Bay State Medical.

These four specific projects had a sizable output of activity:

- *96 start-up life sciences companies housed annually*
- *85 paid student internships*
- *Currently, approximately 50 industry sponsors leveraging MLSC capital investments*
- *Nearly 200 collaborative projects across existing companies, emerging companies, and research institutions annually*
- *Over 200 networking, pitch and workshop events*

State-level Outcomes:

* 901 jobs generated among start-up companies and graduates across the four major incubator/accelerator projects.
* $1.4 billion in private investment dollars attracted to start-up companies assisted by the four major incubator/accelerator projects, including program graduates.

Programmatic Area:
Fostering Seed-Stage and Emerging Industry Development

Recognizing the importance of assisting early-stage and emerging life science companies to advance technology commercialization, the MLSC has implemented programs to provide targeted loans for early-stage and grant assistance to seed-stage companies. These funding programs include the Accelerator Loan Program, the Small Business Matching Grant Program, the Milestone Achievement Program, and the Massachusetts Ramp-Up Program.

Accelerator Loan Program: *Providing working capital to early-stage life science companies.*

Program Inputs:

* Accelerator loans, capped at $1 million per company with a five-year repayment period, have been awarded to 32 companies for a total $23.2 million in support.

Program Outputs:

* Thirteen of the 32 companies have repaid their loans with interest, other loans are maturing through the repayment period.
* Loan recipients have leveraged an additional $252 million in funding (e.g., equity, debt, grants).
* Several CEOs interviewed for this assessment cited the program as vital to their early-stage success by seeing them through funding gaps and helping them attract additional investments. They cited the non-dilutive nature of the loan as being attractive to investors.

State-level Outcomes:

* The number of employees at these companies has increased by about 200 since they entered the loan program.

Accelerator Loan Recipients on the Program's Value:

"Our company would not be here today if not for the loan...which came at such a critical time."

"The significant amount of non-dilutive funding made us more attractive to investors."

"The loan was instrumental in our ability to commercialize technology from MIT."

"[The loan program] is filling an important gap in funding....life science VC funding is moving toward biotech rather than devices."

The Small Business Matching Grant (SBMG) Program: *Providing grants to life science companies with commercialization-ready technologies.*

Program Inputs:

* From 2010 through 2012, the MLSC awarded up to $500,000 to companies poised to commercialize new technologies. The awards granted $3.85 million to eight companies.

Program Outputs:

* Companies leveraged the grants for additional funding (equity, debt, grants, etc.) totaling $75 million.

State-level Outcomes:

* Grant recipients increased their employment by 22 jobs.
* Four of the eight companies realized exits for their founders and investors through acquisition by larger companies.

The Milestone Achievement Program (MAP):

Providing funding to early-stage life science companies to perform and complete essential value-creating milestones.

Program Inputs:

* The program was implemented for one year (2015) during which the MLSC awarded $2.2 million to twelve life science companies. Individual awards ranging from $50,000 to $200,000 were made for milestone-driven projects, which averaged about a year and a half in duration.

Program Outputs:

* Post-program surveys and evaluation conducted by the MLSC found each of the nine responding companies had achieved their targeted milestones.
* Seven of the twelve companies advanced to a higher "stage" in product development (e.g. from prototype to pre-clinical studies).
* Eleven of the twelve companies received subsequent project funding from sources including large biopharma companies, NIH, and other federal sources. The nine responding companies raised more than $36 million.

State-level Outcomes:

* Companies doubled their total employment from 16 to 33.5 full-time equivalent positions.

The Massachusetts Ramp-Up Program (MassRamp): *Supports commercialization activities of companies that have been awarded federal SBIR or STTR Phase I awards.*

MassRamp is MLSC's effort to bridge the funding gaps associated with the lengthy and expensive translation of life sciences R&D into commercial products. Its flexible gap funding can be used to expand the scope of an existing federal innovation grant or to help finance IP protection. While still too new to have measurable outputs or outcomes, the inaugural round of the program in 2017 awarded $1.6 million in funding to eight companies, with grant awards ranging from $75,000 to $300,000.

Programmatic Area:
Scaling Up Life Science Companies

The Tax Incentive Program: *Incentivizing life science companies to create new, long-term jobs in Massachusetts.*

Since 2009, the MLSC has awarded tax incentives to life science companies engaged in R&D, commercialization, and manufacturing in Massachusetts, with the ultimate goal of supporting short- and long-term job creation. The array of available incentives provides working capital to make investments, conduct research, and hire new workers. The incentives also attract out-of-state companies to locate in Massachusetts.

Program Inputs:

* Through seven rounds of the program, the MLSC has made 172 awards worth nearly $157 million.

Program Outputs: In order to receive the tax benefits, participating companies must commit to a target number of new jobs; the agreements include clawback provisions for not meeting a target.

* Clawbacks amount to $55 million, about 35% of the nearly $157 million in tax incentive awards – demonstrating the accountability of the tax incentive program.
* The $102 million of completed and active awards went to 63 companies, often involving multiple awards across years.
* The value of the program was rated a 3.9 on a 5-point scale by companies surveyed.
* Company respondents generally "agree" that the awards helped them to hire new employees beyond their target goals, invest in additional research capacity, and commercialize new products.

State-level Outcomes:

* Hiring reached 8,703 jobs through 2016 by participating companies in the tax incentive program, exceeding their program-specific hiring goals of 4,721.
* This level of new hiring among companies receiving MLSC tax incentives could be expected to generate an additional $60 million in annual tax revenue for the Commonwealth. This is estimated by applying the average life science industry wage of $135,200 against Massachusetts' 5.1%income tax rate for 2017. If the new jobs are retained in-state, these tax receipts could more than offset the cumulative incentive.

Fig. 15: Tax Incentive Program Survey:
The Program Incentives Have Helped our Company...
(Scale: 1 = "Strongly Disagree" - 5 = "Strongly Agree")

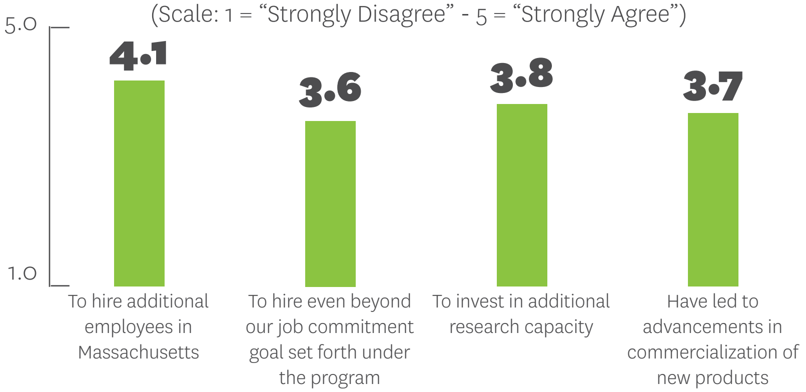
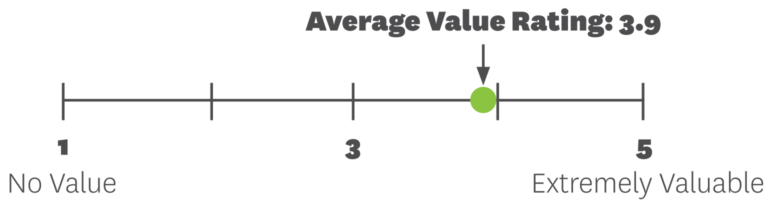


Fig. 16: Tax Incentive Program Survey:
Value of the MLSC Program Incentives



Programmatic Area:
Strengthening Connections and Diversity of Talent

The MLSC has designed and implemented multiple programs focused on enhancing secondary and post-secondary educational offerings and creating a life sciences talent pipeline through workforce development. The programs include capital grants for middle and high schools serving populations that are under-represented in STEM careers, capital grants for higher education workforce training facilities, and programs to facilitate direct placement of college students in paid internships. Combined, these programs aim to develop a diverse, skilled workforce for life science-related careers to help address issues of under-representation of women and some racial and ethnic minorities in STEM fields in Massachusetts (see Figure 17).

STEM Equipment & Supplies Grant Program:

Enabling the purchase of equipment and supplies for high schools and middle schools in order to train students in life sciences technology and research, increase student achievement and interest in STEM, and to implement state STEM standards.

Program Inputs:

* Since 2011, the MLSC has funded the purchase of STEM-related equipment and supplies in Massachusetts middle schools (grants up to $50,000) and high schools and vocational/technical schools (grants up to $250,000, with a 1:1 matching requirement from industry). As shown in Figure 18, a significant number of these grants have gone to schools in the central and western portions of the Commonwealth. This is also true of the capital investments in higher education (see Figure 19).

Fig. 17: Share of STEM and All Jobs by Sex and Race/Ethnicity in MA (2015)

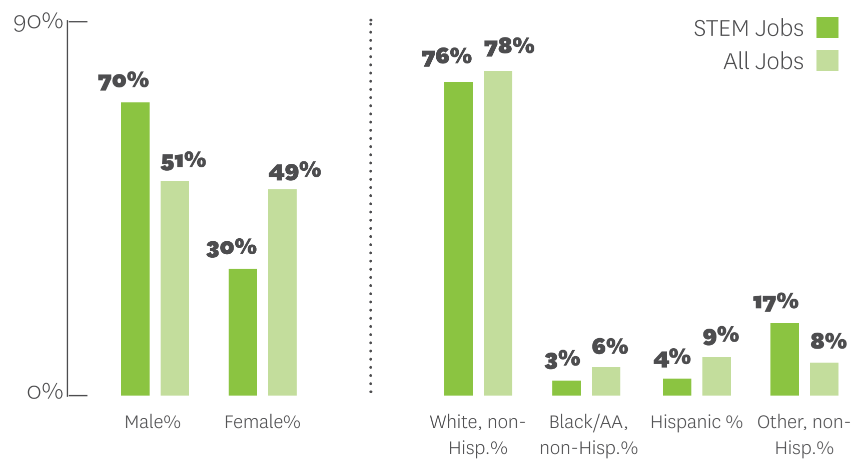


Fig. 18: Distribution of STEM Equipment & Supplies Grants Across MA

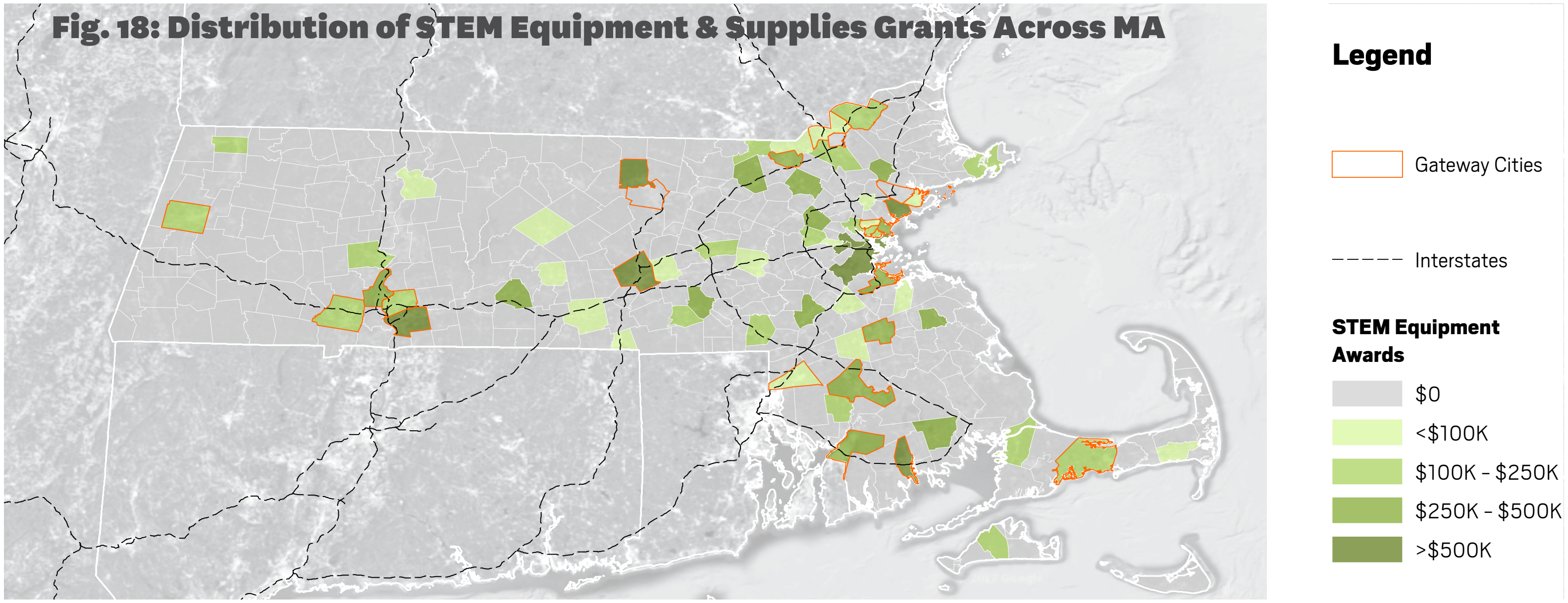
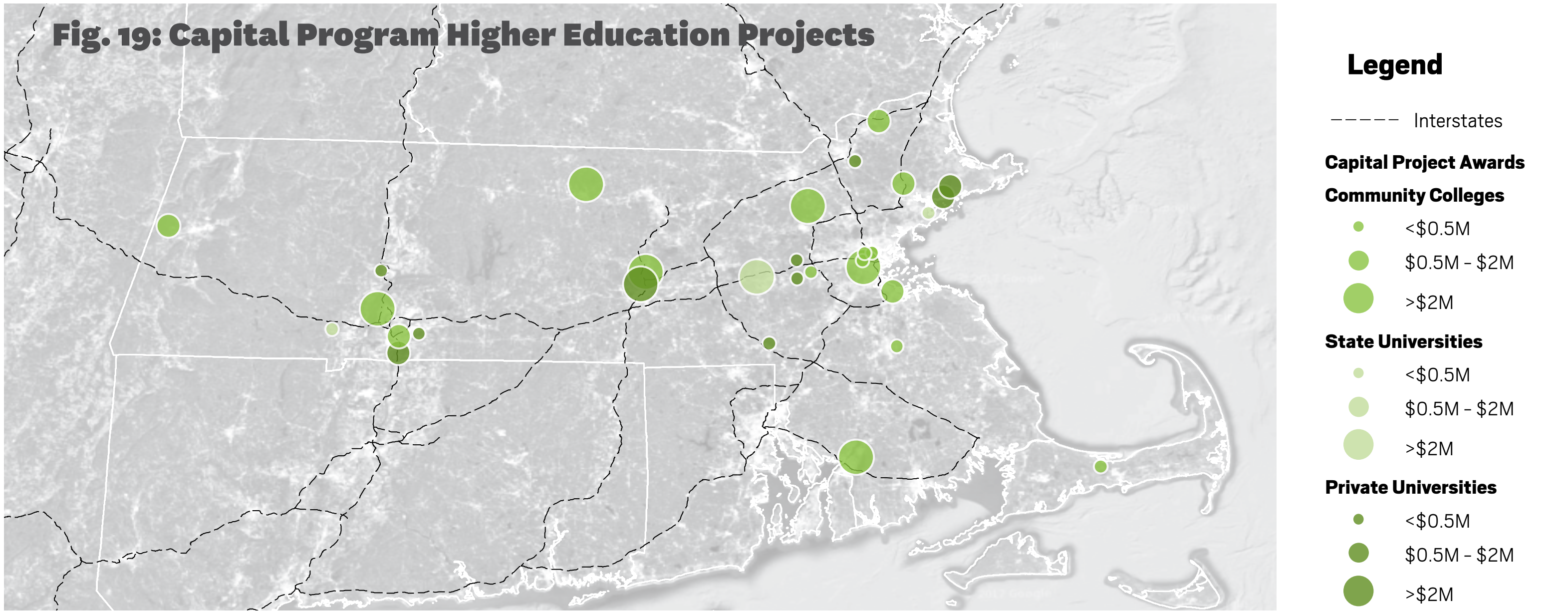


Fig. 19: Capital Program Higher Education Projects



* In total, the MLSC has awarded $16.6 million to 149 schools meeting the eligibility criteria, which include vocational-technical schools, schools with over 25 percent of students deemed "economically disadvantaged," and schools located in "Gateway Cities" (mid-sized, economically distressed urban centers). Included in this program funding for FY 2017 is nearly $400,000 for teacher professional development for teachers who will utilize the equipment.

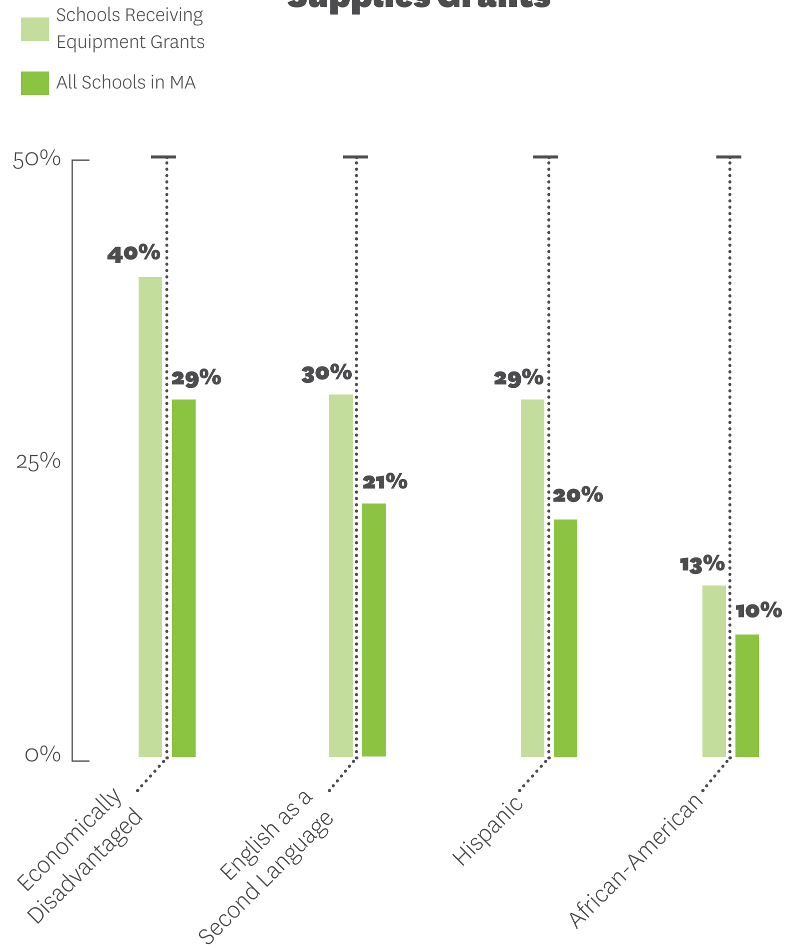
Program Outputs:

* The program's leverage requirement has brought in more than $1 million in industry matching funds and in-kind contributions.
* Schools receiving equipment grants are serving a more diverse and higher need student body than state averages, true to the program's goal of increasing access to high-quality STEM education. (See Figure 20.)
* According to school officials interviewed, the MLSC STEM equipment grants have increased student engagement and excitement by providing the opportunity for middle and high school students to experience working with sophisticated equipment used in professional labs.

"Using equipment funded by MLSC, students used PCR to amplify a non-coding portion of mitochondrial DNA from their own cheek cells and then sent the samples away for DNA sequencing. Students used bioinformatics to determine their own haplotype."

– Jonathan Shapiro, Science Department Head, Brockton High School

Fig. 20: Socioeconomic Characteristics of Student Populations Receiving STEM Equipment/ Supplies Grants



23% of public middle and high school students attend a school which has received an MLSC STEM grant

69% of grants have gone to economically disadvantaged schools

The Internship Challenge Program: *Enhancing the talent pipeline for Massachusetts life sciences companies by facilitating the placement of college students and recent graduates in paid internships.*

Program Inputs:

* The program reimburses companies up to $17 per hour for 480 hours (twelve 40-hour weeks) for each intern, for a maximum of $8,160 per intern. Total program expenditures to date have been $20.7 million.
* Since the program launched in 2009, the Center has funded 3,170 interns at 649 life science companies, enabling career exploration, creating opportunities for mentoring, and expanding the pool of college graduates with life sciences experience.

Program Outputs:

* Value for industry participants: An MLSC survey of employers participating in the internship program found (see Figure 21):
* *89% of 72 surveyed employers said they would not have hired interns in the program year were it not for the program.*
* *Employers indicated broad satisfaction with the program — all indicated they would participate again and recommend the program to other companies.*

Fig. 21: Intern Challenge: Employer Survey

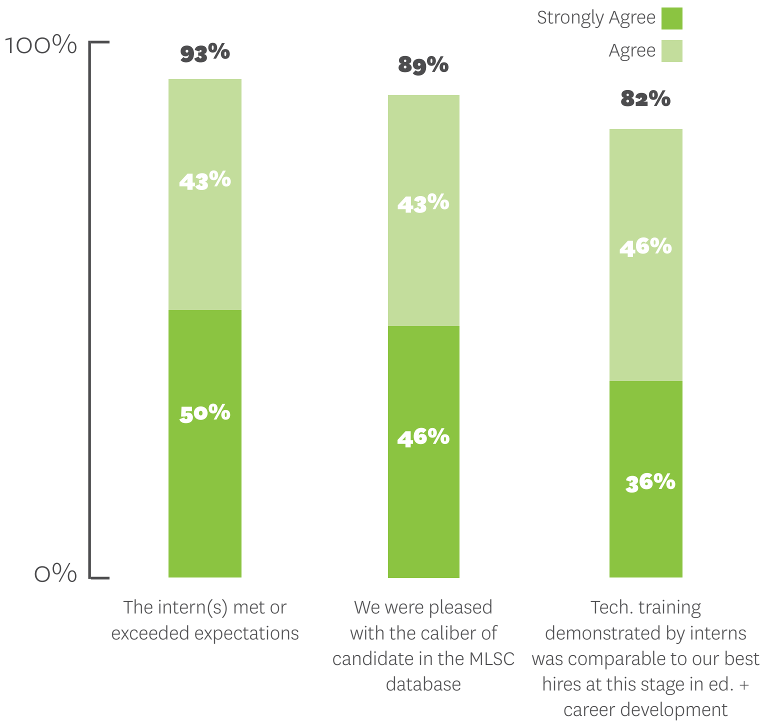
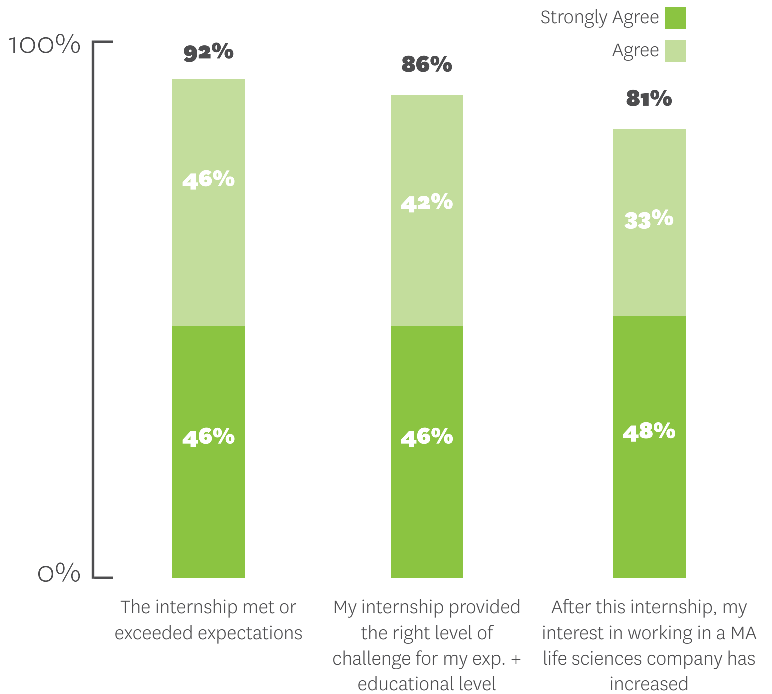


Fig. 22: Intern Challenge: Intern Survey



* *Employers reported that the program is effective in providing helpful temporary support and reduces the risk of offering full-time employment.*
* *The most frequent suggestion for improvement was "more" in terms of the number of internships available and expansion of the program to non-summer months.*

* Value for student interns: Students surveyed report broad satisfaction as well (see Figure 22):
* *More than 90% of 138 surveyed interns report the experience met or exceeded expectations.*
* *A strong majority (more than 80%) report increased interest in working in the life sciences field.*

State-level Outcomes:
* Since program inception, 634 interns (20%) have been hired post-internship by their host employer in either part- or full-time positions.
* These hires and connections span all regions of the state and subsectors of the life science industry.

Capital Investments in Higher Education Projects: *Advancing the talent pipeline and industry access for postsecondary students through customized workforce development programming and facilities.*

One of the three major areas for MLSC Capital Program investments has been for advancing life science-related educational programs and capabilities in higher education institutions. In order to better serve industry needs for a robust local talent pipeline, Massachusetts' community colleges and private universities are utilizing the MLSC investments to upgrade existing and build new laboratory infrastructure, to purchase lab equipment and materials, to establish new courses and life science-related degree programs, and to increase STEM majors and graduates.

Program Inputs:
* Since 2009, 31 MLSC-funded capital projects have been awarded totaling $46 million to community colleges, private universities, and non-profit organizations for upgrading STEM and life science-related instructional facilities.

Program Outputs:
* Annual reports from program recipients cite $34.3 million in additional funds leveraged by these MLSC investments to advance new education and training capabilities.
* Through FY 2016, 80% of awards have been to public colleges and universities, with 70% going to the state's public two-year colleges and certificate programs. All but one of Massachusetts's community colleges have received equipment grants from the MLSC. Because community colleges provide developmental education, affordable tuition, financial aid and flexible, and part-time scheduling, they remove barriers faced by students traditionally underrepresented in STEM fields. (See Figure 23.)

State-level Outcomes:
* Capital investments in higher education have supported 64 FTE jobs.

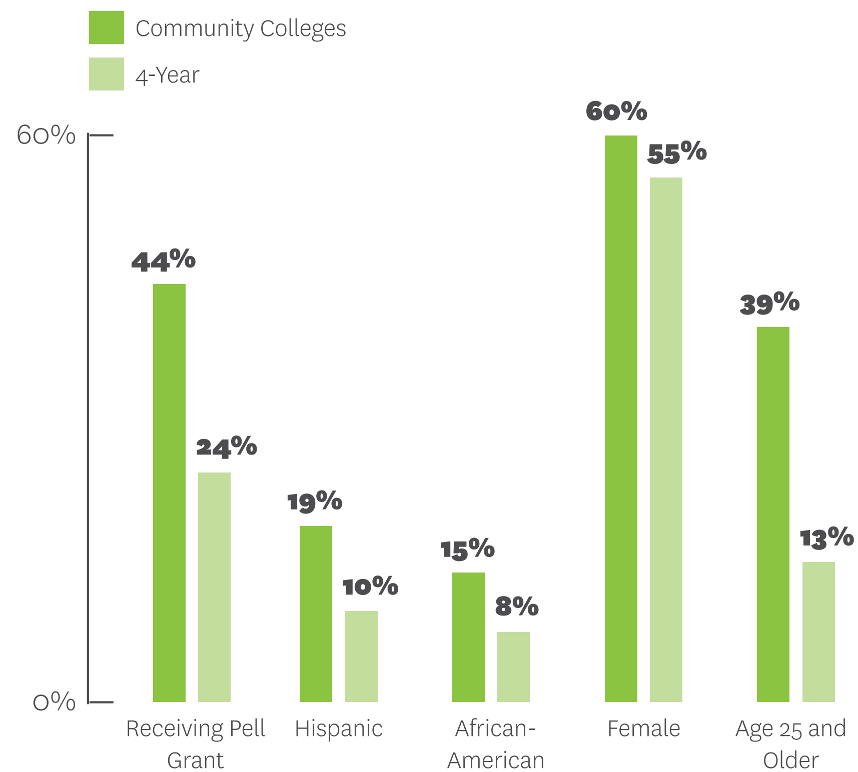
Examples of Broader Outcomes Advancing Massachusetts' Life Science-related Education and Training Capacities:

* To assess impacts and outcomes, we examined three of the larger projects funded in the MLSC's first five years that are now operational.

* **Worcester Polytechnic Institute** established the Biomanufacturing Education and Training Center (BETC) utilizing, in part, $2.95 million in funding from the MLSC to purchase specialized equipment and to help outfit the BETC's physical space. The BETC, which opened in 2013, offers a unique 10,000-square-foot facility for flexible, hands-on training that can be customized to meet individual company needs in biomanufacturing. Today, the BETC offers nine one- to five-day "open enrollment" programs for industry professionals, primarily manufacturing technicians and operators and engineers. BETC also designs and hosts customized training courses created specifically for its sponsor companies and other companies in Massachusetts, serving eleven biotech and pharmaceutical companies to date, often with repeat engagements. In addition, the BETC is currently running a graduate program for a Master's in Biotechnology, combining online coursework with lab work held in the BETC. In the last five years, the BETC estimates that more than 1,300 industry professionals and students have completed a training course.

* **Northern Essex Community College** used its $1.2 million capital program award in 2012 to renovate four existing labs on the Haverhill campus, construct a new lab in Lawrence, and purchase new lab materials and equipment. The funding for state-of-the-art labs has helped enable the college to offer a new, stand-alone Associate's degree program in Biology (which currently has more than 700 enrolled) and has enhanced its ability to offer a more complete lab sciences program, including courses in cell biology and ecology. The estimated number of students served by these laboratories reaches about 1,300 per semester.

Fig. 23: Students Served by MA Colleges and Universities



* **Framingham State University** utilized a $3 million MLSC investment to purchase lab equipment as part of a larger $80 million project to construct a new lab building for its biology, chemistry, and food science programs. Responding to local industry demand, the lab building and new equipment was utilized to establish several new programs, including a Professional Master's degree in Biotechnology and a new Biochemistry major, both of which have 20 students enrolled; a new "4+1" Bachelor's/Master's program in Biotechnology; and a biotechnology focus option within the school's MBA program. Enrollment in STEM programs has grown at FSU and leadership cites the new building and the MLSC funded equipment as contributing factors.

Summing Up:
Measuring the Contributions of the MLSC Across Companies Assisted

One way to summarize the contributions of the MLSC on life sciences development is to focus on the 115 companies directly assisted through its programs – whether those companies are at the stage of commercialization, business formation or investment-ready growth. These companies reflect the near-term contributions that the MLSC is making towards tangible development goals of increasing investment, commercialization, and jobs. As a group, these companies have had rapid absolute levels of job growth and higher productivity compared to the broader life sciences performance in the Commonwealth:

* Job growth among MLSC companies totaled 8,940 from employment levels reported at the time of assistance through 2016; their approximately 50% job growth compares favorably with overall life sciences job growth of 14% from 2009 through 2016.

* Venture capital (VC) investments in MLSC companies totaled $2.1 billion from 2009 through late 2017, with an average of $61 million invested per VC-funded company compared to $39 million for all VC-funded life sciences firms in Massachusetts.

* Patent activity among MLSC-supported companies averaged 42 patents per firm (3,460 total patents) compared with about 6 patents per firm across the life sciences cluster.

* SBIR/STTR awards for MLSC-supported companies totaled 72 from 2009-16 with $76 million in funding; SBIR funding for these firms was $1.2 million higher than the average for all life science firms in the Commonwealth, underscoring the success of MLSC-supported companies in winning Phase II SBIR awards.

* Clinical trials sponsored by MLSC-assisted companies totaled 453, representing 9.1% of all industry-led clinical trials in Massachusetts during this period.

The MLSC impacts by program area are summarized in Figure 24.

Fig. 24: Summary of the Direct Contributions of MLSC Programs

MLSC Themes	Investing in Innovation Infrastructure for the Future	Fostering Seed-Stage and Emerging Industry Development	Scaling Up Life Sciences Companies	Strengthening Connections and Diversity of Talent
Life Sciences Ecosystem Needs & Gaps	-Specialized infrastructure -Enhanced research capabilities -Accelerated commercialization -Space for new, growing co.'s -Connecting industry + univs.	-Validating technology -Valley of death in commercialization -Attracting capital -Building entrepreneurial management team	-Long development lead times -High research costs -Clinical trials -High costs to attract and train qualified workforce	-Generating a STEM talent pipeline -Need for work experience -Engage diverse talent base
MLSC Programs	-Capital Program for Research -Capital Program for Incubators/Accelerators -Neuroscience Consortium	-Accelerator Loans -Small Business Matching Grants -Milestone Achievement Program	-Tax Incentive Program	-STEM Eqpmt. and Supplies -Internship Challenge -Capital Program for Higher Education
Results	-$1.67 leveraged for every $1 invested -Major new federal research grants generated -Specialized scientific talent trained -New industry collaborations with researchers and start-up companies -901 jobs and $1.4 billion in private investment generated by start-up companies assisted	-52 companies assisted at early stage of development -$363 million in private and other investment generated -237 new jobs created	-8,703 new jobs added through FY 2016 by 63 companies actively involved or completed program -Estimated $60M in annual tax revenues generated by new hiring, helping to offset program incentives -Rated 3.9 on a 5 point scale in survey of industry participants pointing to significant value of program	-149 under-resourced schools assisted -Greater than $1M industry match for STEM equipment and supplies -3,170 college interns at 649 life science companies -20% of interns hired by host companies -New community college/ university degree programs, corporate customized training developed with expanded capabilities

Section 3 Assessing the Impact of the MLSI on the Massachusetts Life Sciences Clusters

This section uses a "but-for" analysis to assess the overall impact of the MLSI on the life sciences cluster in Massachusetts. We perform this analysis by examining the nature and scale of change in the performance of the Massachusetts' life sciences cluster in the 2009-2016 period and compare these changes to what we would predict based on life sciences trends in Massachusetts and peer states in the pre-MLSI 2003-09 period.

To assess the impact of the MLSI on the Massachusetts life sciences cluster, simplifying assumptions must be made. The first is that in the absence of the MLSI, the evolution of the cluster in the 2009-2016 period would have followed the patterns established in the 2003-2009 period. This sets a high bar, as job and wage growth in the Commonwealth in 2003-2009 period was extremely high in absolute terms (+15,000 jobs) and in growth relative to nation (22% versus 11% for the U.S.) and to peer states (second only to North Carolina). The second is that deviations from these patterns can be attributed to the climate created by and the specific investments made as part of the MLSI. The third is that the best way to estimate the likely trajectory of Massachusetts life sciences in the absence of the MLSI is to identify and track a set of peer states and activity in their clusters in the 2003-2009 and 2009-2016 periods.

There are two challenges to the "but-for the MLSI" evaluation, both of which will bias the results downward, i.e., underestimate the positive impact of the MLSI. The first is that "but-for" analyses are predicated on the assumption that changes in peer growth in the second period (here, 2009-2016) provide a proxy for how the Massachusetts life sciences cluster would have evolved in the absence of the MLSI. However, while Massachusetts' $1 billion investment was widely heralded at the time it was announced, as the decade unfolded it is just one of many significant state efforts undertaken across the U.S. In addition to state investments, across the U.S., local and regional efforts to promote life sciences growth provide support like research and training and access to angel capital. In short, part of the positive effect of the MLSI will be obscured by initiatives in peer states that raise life science growth rates in the but-for analyses. Unfortunately, there is no way around this problem: although there are states that have had little or no policy intervention in the life sciences, none of these could remotely be considered a peer to Massachusetts. Among peers, the numbers and types of interventions at the local, regional, and state levels are too numerous to catalogue, making it impossible to get a clean estimate of the investments made by the but-for comparators used in the analysis.

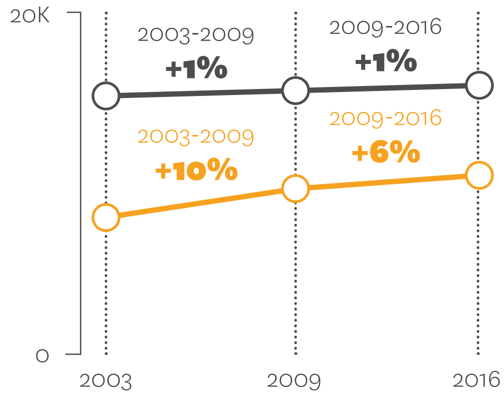
A second issue is that while the MLSI investments will have short- and long-term impacts, the but-for analysis only captures the impact of the MLSI in the 2009-2016 period, missing longer-term MLSI-driven growth. The evaluation presented in Section 1 shows Massachusetts slightly outperforming peers in terms of ecosystem development in 2009-2016, suggesting that post-MLSI, conditions for long-term life sciences job growth were strengthened. Moreover, specific programmatic investments—things like fostering cutting-edge research at the state's universities and establishing incubators and accelerators to help entrepreneurs translate science into products and firms—are almost certain to yield benefits that will not yet be evident in the Commonwealth's jobs and wage numbers.

Fig. 25: Life Sciences Sub-Cluster Employment Growth for MA and Peer States (2003-2016)

Drugs and Pharmaceuticals

State (2009 Rank)	2009 Jobs
CA (1)	43,400
NJ (2)	34,000
NC (3)	20,400
IN (4)	18,000
TX (5)	9,900
MA (6)	9,700
MD (7)	6,400
FL (8)	5,500
UT (9)	4,600
MN (10)	3,500

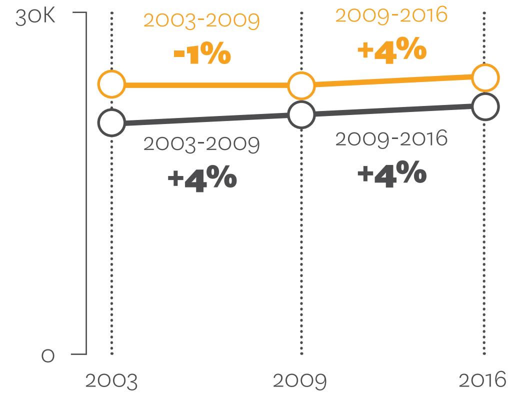
Job Growth over Time



Medical Devices and Equipment

State (2009 Rank)	2009 Jobs
CA (1)	67,300
MN (2)	28,900
MA (3)	23,100
FL (4)	22,000
IN (5)	19,400
NJ (6)	14,500
TX (7)	13,700
UT (8)	8,800
NC (9)	8,400
MD (10)	2,300

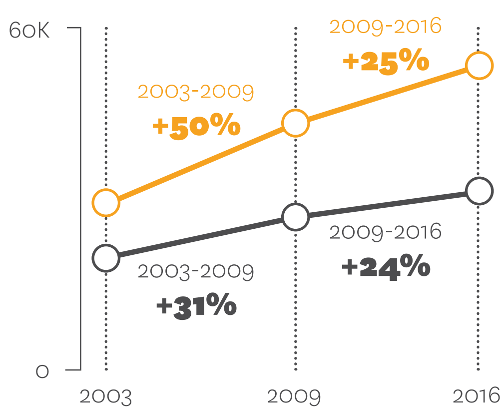
Job Growth over Time



Research, Testing, and Medical Laboratories

State (2009 Rank)	2009 Jobs
CA (1)	82,200
MA (2)	43,800
NJ (3)	30,400
TX (4)	23,200
MD (5)	22,600
NC (6)	20,300
FL (7)	17,200
IN (8)	7,900
MN (9)	6,700
UT (10)	6,100

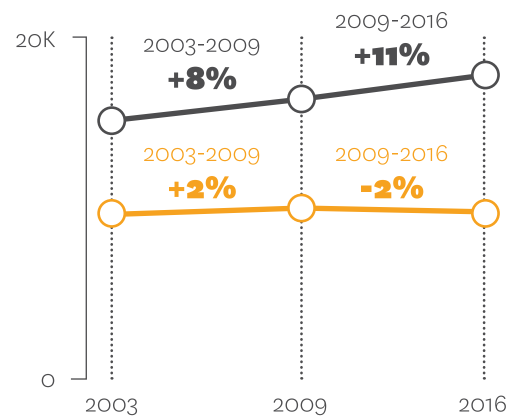
Job Growth over Time



Bioscience-related Distribution

State (2009 Rank)	2009 Jobs
CA (1)	41,500
FL (2)	33,400
TX (3)	27,300
NJ (4)	18,600
NC (5)	10,800
MA (6)	9,800
IN (7)	7,200
MN (8)	6,000
MD (9)	5,400
UT (10)	3,700

Job Growth over Time

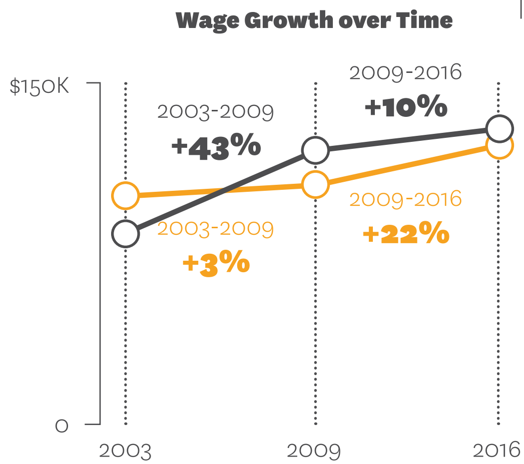


MA —
Peer avg. —

Fig. 26: Life Sciences Sub-Cluster Wage Growth for MA and Peer States (2003-2016)

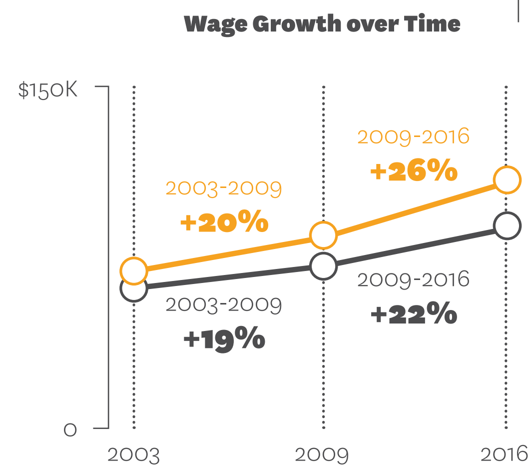
Drugs and Pharmaceuticals

State (2009 Rank)	**2009 Avg Wage**
CA (1)	**$149,300**
NJ (2)	**$133,500**
IN (3)	**$112,900**
MA (4)	**$101,800**
MD (5)	**$94,000**
NC (6)	**$87,100**
TX (7)	**$83,700**
MN (8)	**$71,400**
FL (9)	**$58,400**
UT (10)	**$50,300**



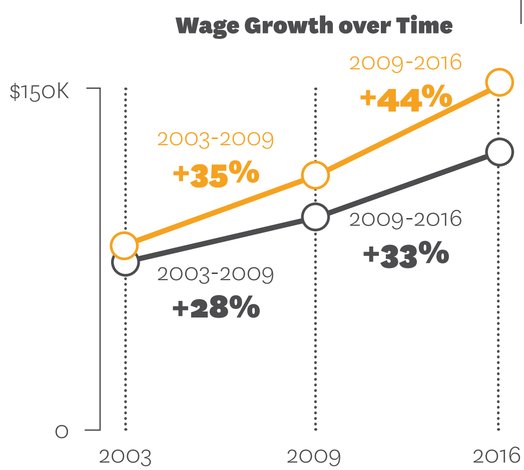
Medical Devices and Equipment

State (2009 Rank)	**2009 Avg Wage**
NJ (1)	**$88,100**
MA (2)	**$85,700**
CA (3)	**$85,000**
MN (4)	**$79,000**
MD (5)	**$65,900**
IN (6)	**$61,300**
FL (7)	**$57,200**
TX (8)	**$56,200**
UT (9)	**$53,300**
NC (10)	**$52,300**



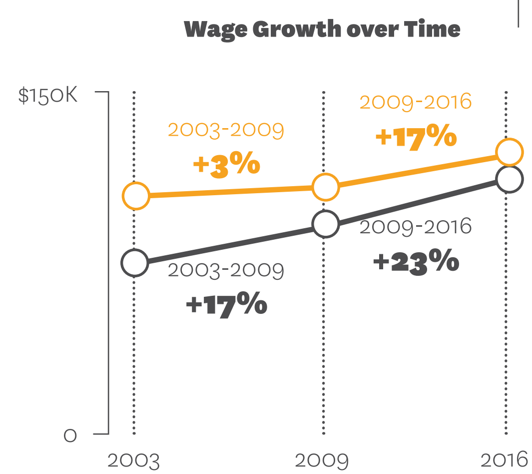
Research, Testing, and Medical Laboratories

State (2009 Rank)	**2009 Avg Wage**
NJ (1)	**$111,500**
MA (2)	**$105,600**
CA (3)	**$101,900**
MD (4)	**$89,100**
NC (5)	**$77,500**
MN (6)	**$76,000**
TX (7)	**$71,400**
UT (8)	**$63,500**
FL (9)	**$63,100**
IN (10)	**$58,300**



Bioscience-related Distribution

State (2009 Rank)	**2009 Avg Wage**
NJ (1)	**$115,300**
MA (2)	**$101,800**
MN (3)	**$93,400**
IN (4)	**$89,600**
TX (5)	**$87,600**
MD (6)	**$85,800**
CA (7)	**$84,800**
FL (8)	**$80,300**
NC (9)	**$76,000**
UT (10)	**$69,400**



MA —
Peer avg. —

Results

As shown in Figure 25, in the 2009-2016 period, Massachusetts job growth was faster than the (weighted) average of its peers in drugs and pharmaceuticals (6% vs 1%) and research, testing, and medical laboratories (25% vs 24%); identical in medical devices and equipment (4% vs 4%), and lower in bioscience-related distribution (-2% vs +11%). When location quotient is used as the metric, Massachusetts outperforms its peers in every sub-cluster except bioscience-related distribution, a pattern that is repeated when average wages are compared. (See Figure 26.)

This very strong performance in the post-2009 period, however, is actually weaker than the 2003-2009 trajectory would predict. In other words, although absolute job performance against the national average and against a smaller set of strong life science states ("peers") was strong in the 2009 to 2016 period, it failed to keep pace with Massachusetts' 2003 to 2009 performance, when a 50% surge in jobs in research, testing, and medical laboratories drove overall life sciences growth of 22%. As a result, compared to the 2003 to 2009 trajectory, Massachusetts underperformed its peers by about 8,700 jobs. If instead we use location quotients to compare Massachusetts versus peer

Fig. 27: "But-For" Analyses: MA Life Sciences Growth Relative to Peers (2009-2016)

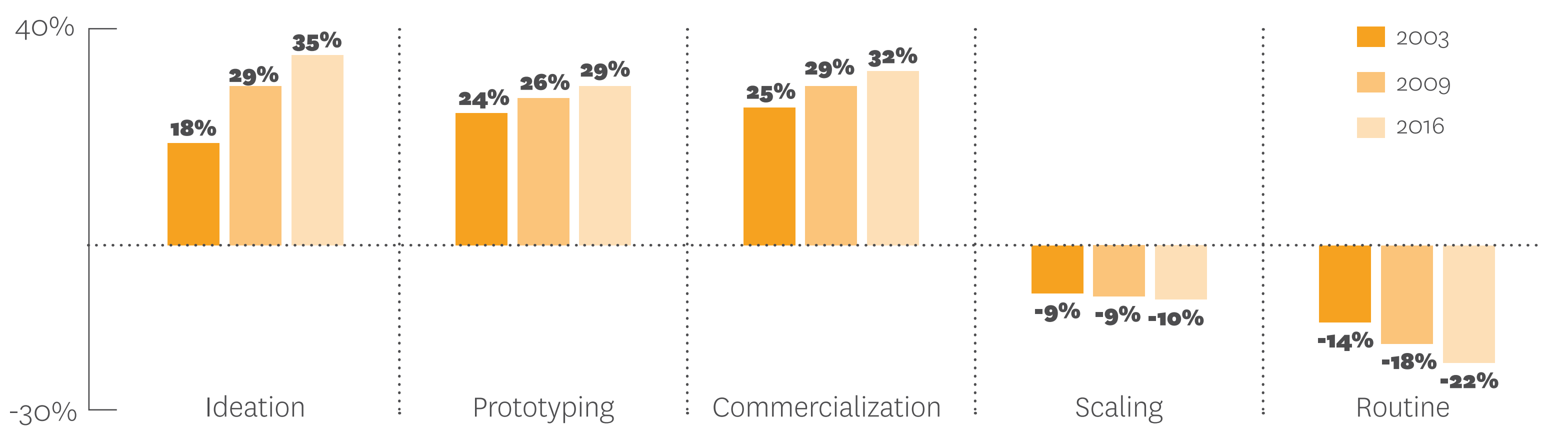
	MA 2009-2016		**MA vs Peers 2009-2016**		**But-For**	
	Absolute Growth	**Actual vs Expected**	**Absolute Growth**	**Actual vs Expected**	**Actual vs Expected (Absolute)**	**Actual vs Expected (LQ)**
	MA Growth 2009-16	MA Growth 2009-16 (vs U.S. Industry Growth)	MA Growth Relative to Peers, 2009-16	MA Growth Relative to Peers, 2009-16 (vs U.S. Industry Growth)	2009-16 Growth Relative to 2003-09 Growth vs Peers	2009-16 LQ Growth Relative to 2003-09 Growth vs Peers
Jobs	12,500	2,800	2,900	-370	-8,700	-6,800
Wages ($M)	$4,785	$1,050	$1,675	$400	-$130	$1,030

growth in the pre- and post-MLSI periods—an approach that captures economy wide trends in state employment—the "but-for" estimate of the MLSI impact is -6,800 jobs.

Focusing on wages, the short-term "but-for" tells a positive story. In absolute terms, life sciences wages in Massachusetts grew $4.8 billion from 2009 to 2016, $1.1 billion more than expected based on national averages. Relative to the strong 2003 to 2009 trend versus peer states, Massachusetts underperformed peers by about $130 million. If instead we use a location quotient approach—which looks at life science wage growth relative not only to peer state trends but to secular trends in the Commonwealth's economy—we estimate a "but-for" impact of +$1 billion in the post-2009 period. (These analyses are summarized in Figure 27.)

These trends, including the diametric outcomes for jobs and wages, are consistent with the correlative concentration of Massachusetts life science activity in ideation (R&D), prototyping, and commercialization rather than more routine activities like manufacturing and distribution. Although the early stages of the innovation trajectory pay higher wages, the largest concentration of jobs is in routine activities, which account for half of all life sciences jobs in the U.S. As shown in Figure 28, as of 2016, Massachusetts had 35% more life science cluster jobs in ideation than the national average but 22% fewer routine jobs. These trends suggest, as well, that realizing the full job creation potential of MLSI investments will require identifying strategies to grow, attract, and retain activities that are downstream from R&D, such as medical device and drug/pharma manufacturing and bioscience distribution. Success in capturing downstream activities growing out of the Commonwealth's life sciences innovations could support strong future job growth.

Fig. 28: MA Share of Employment (Relative to U.S.) by Stage of Innovation



Appendix

Appendix A: Peer State Selection

In this report, we assess Massachusetts' life sciences performance in relation to the performance of peer states. To select appropriate peer states, we identified criteria to determine strong life sciences cluster performance: a substantial number of life sciences jobs, the cluster's importance to the state's total economy, multiple sub-cluster specializations, and strong cluster growth. Our final peer state selection criteria were:

* Significant number of jobs in the life science cluster
  * *Metric: Number of life sciences jobs in state exceeds the upper quartile for life sciences jobs among U.S. states in 2009*

* Numerous life sciences cluster jobs relative to the size of the state economy
  * *Metric: life sciences cluster location quotient greater than or equal to 1.2 in 2009*

* Strong life sciences cluster growth, both in absolute terms and relative to U.S. trends
  * *Metric: Actual number of life sciences jobs in state in 2009 greater than expected number of life sciences jobs (using 2003-2009 national growth rates)*

* Significant life sciences sub-cluster specializations
  * *Metric: location quotient greater than or equal to 1.2 in 2009 for at least two of three life sciences sub-clusters (Research, Testing and Medical Labs, Drugs and Pharmaceuticals, or Medical Devices and Equipment)*

* High average wages
  * *Metric: State's average life sciences wages greater than the U.S. average life sciences wages in 2009*

If a state met the established criterion for a metric, that state was given a point, for a possible total of five points across all the measures. States with a total score of less than two were eliminated from consideration, narrowing the field of potential peer states to only twelve states. To avoid including states with life sciences clusters in decline—which could overstate the impact of the MLSC/MLSI on Massachusetts growth—job growth leading up to 2009 was considered an essential factor in choosing peer states. Three states (Pennsylvania, Connecticut, and Illinois) with an absolute decline in life sciences jobs in the 2003-2009 period were dropped, leaving nine peer states. Among these nine peer states, four states emerged as leaders: California matched on all five metrics, while North Carolina, New Jersey, and Indiana matched on four of the five criteria. Minnesota, Maryland, and Utah scored three points each and had one or more key sub-cluster specializations, while Florida and Texas (with two points each) had not yet reached the concentration of the other states but had sizable and notable life sciences growth from 2003 to 2009. The project team included all nine peer states in order to develop comparisons against a set of states spanning leaders, those competing in key sub-cluster specializations, and emerging "up-and-comers." (See Table A-1.)

Table A-1: Benchmark Measures Summary

2009 Life Sciences Jobs Rank (all States)	States	Life Sciences Jobs, 2009	Life Science Job Growth, 2003-09	Life Science Job Concentration, 2009	Life Science Specializations, 2009	Life Science Average Wage, 2009	Total Points
1	CA	Y	Y	Y	Y	Y	5
4	MA	Y	Y	Y	Y	Y	5
2	NJ	Y	N	Y	Y	Y	4
3	PA	Y	N	Y	Y	Y	4
9	NC	Y	Y	Y	Y	N	4
10	IN	Y	Y	Y	Y	N	4
11	MN	Y	Y	Y	N	N	3
14	MD	N	N	Y	Y	Y	3
17	CT	N	N	Y	Y	Y	3
23	UT	N	Y	Y	Y	N	3
6	FL	Y	Y	N	N	N	2
7	TX	Y	Y	N	N	N	2
8	IL	Y	N	N	N	Y	2

(Shaded rows: PA, CT, IL) States eliminated as peers due to their absolute decline in Life Sciences jobs

Table A-2: Life Sciences Cluster Definition

NAICS	NAICS Title	Life Sciences Sub-cluster
325411	Medicinal and Botanical Manufacturing	Drugs & Pharmaceuticals
325412	Pharmaceutical Preparation Manufacturing	Drugs & Pharmaceuticals
325413	In-Vitro Diagnostic Substance Manufacturing	Drugs & Pharmaceuticals
325414	Biological Product (except Diagnostic) Manufacturing	Drugs & Pharmaceuticals
334510	Electromedical and Electrotherapeutic Apparatus Manufacturing	Medical Devices & Equipment
334516	Analytical Laboratory Instrument Manufacturing	Medical Devices & Equipment
334517	Irradiation Apparatus Manufacturing	Medical Devices & Equipment
339112	Surgical and Medical Instrument Manufacturing	Medical Devices & Equipment
339113	Surgical Appliance and Supplies Manufacturing	Medical Devices & Equipment
339114	Dental Equipment and Supplies Manufacturing	Medical Devices & Equipment
339115	Ophthalmic Goods Manufacturing	Medical Devices & Equipment
333314	Optical Instrument and Lens Manufacturing	Medical Devices & Equipment
541380 (partial)	Testing Laboratories	Research, Testing, & Medical Laboratories
541712 (partial)	Research and Development in the Physical, Engineering, and Life Sciences (except Biotechnology)	Research, Testing, & Medical Laboratories
621511	Medical Laboratories	Research, Testing, & Medical Laboratories
541711	Research and Development in Biotechnology	Research, Testing, & Medical Laboratories
423450 (partial)	Medical, Dental, and Hospital Equipment and Supplies Merchant Wholesalers	Bioscience-related Distribution
424210 (partial)	Drugs and Druggists' Sundries Merchant Wholesalers	Bioscience-related Distribution

Note that Agricultural Biosciences are excluded from the definition

Sources

Fig 1: TEConomy/Mass Economics analysis
Fig 2: TEConomy
Fig 3 – 4: Implan; Mass Economics analysis
Fig 5 – 7: Mass Economics' Urban Data Platform (UDP)
Fig 8: National Science Foundation, National Center for Science and Engineering Statistics; U.S. Census Bureau, Business R&D and Innovation Survey, 2010-2015; NIH RePORT; NSF's Higher Education Research and Development Survey; TEConomy analysis
Fig 9: Thomson Reuters' Eikon database; SBIR/STTR data; TEConomy analysis
Fig 10: U.S. Patent and Trademark Office; TEConomy analysis
Fig 11: BLS, Occupational Employment Statistics; TEConomy analysis
Fig 12: NIH RePORT; NSF's Higher Education Research and Development survey; Thomson Reuters' Eikon database; SBIR/STTR data; U.S. Patent and Trademark Office; BLS, Occupational Employment Statistics; TEConomy analysis
Fig 13: NIH RePORT; NSF's Higher Education Research and Development survey; Thomson Reuters' Eikon database; SBIR/STTR data; U.S. Patent and Trademark Office; BLS, Occupational Employment Statistics; Implan; TEConomy/Mass Economics analysis
Fig 14: TEConomy/Mass Economics analysis
Fig 15: TEConomy survey of companies receiving tax incentives
Fig 16: TEConomy survey of companies receiving tax incentives
Fig 17: American Community Survey – IPUMS, 2011-2015 5-year release; Mass Economics Analysis
Fig 18 – 19: MLSC data; Mass Economics analysis
Fig 20: MLSC data; MA Department of Education data; Mass Economics analysis
Fig 21: MLSC survey of employers participating in the Internship Challenge Program
Fig 22: MLSC survey of interns participating in the Internship Challenge Program
Fig 23: National Center for Education Statistics – Integrated Post-Secondary Education Data System; Mass Economics analysis
Fig 24: TEConomy/Mass Economics analysis
Fig 25 – 28: Implan; Mass Economics analysis
Table A-1: Implan; Mass Economics analysis
Table A-2: TEConomy